TROPICAL AGRICULTURE

THE JOURNAL OF THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

VOL. XXIX APRIL–JUNE, 1952 NOS. 4–6

Acting Editor
G. HAVORD, B.SC. (Lond.), A.R.I.C.

TROPICAL AGRICULTURE is published by the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, British West Indies. Subscription rates can be obtained from the Head of the Library and Publications Department at the above address, or from the Secretary of the College, 40, Norfolk Street, Strand, London, W.C.2, England. Authoritative articles for publication should be submitted to the Editor for consideration. Cables: Stomata. Phone: St. Augustine, 94419. *It is understood that opinions expressed or recommendations made in signed articles or in articles of which the source is named are those of the author and do not necessarily represent the policy or opinion of the College Authorities.* Increasing numbers of inquiries are being received from the various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence is invited on all other matters pertaining to tropical agriculture and related subjects.

EDITORIAL

THE RECENT DEVELOPMENT OF THE DEPARTMENT OF AGRICULTURE, I.C.T.A.

FOR the first time for many years the staff of the Department of Agriculture of the College is almost up to full establishment and is approaching adequacy to meet its teaching and investigational commitments. The staff moved from its totally inadequate offices in the Main Building into the " Old Biology Building "—the original building of the College—early in 1951, when this was vacated by the accommodation of the Biological Departments in the new Frank Stockdale Laboratories.

The department is now able to develop much improved agricultural training for the many types of students for which it has to cater. The basis of training is the use of a *farm* as a teaching and demonstration unit, and the use of the land and other facilities of the farm for students' research and study projects.

The New Farm is situated about three miles west of the College, straddling the Churchill-Roosevelt Highway, on about 300 acres of land made available three years ago by the Government of Trinidad and Tobago. In addition a

further 60 acres are available on the Old Farm within College grounds and on lands provided by the Empire Cotton Growing Corporation in 1942. There are also available 3 acres of irrigated land for work on the rice crop. The farm is still in the early stages of development and does not yet afford adequate facilities for research and training.

In 1947 the whole of the New Farm land was under dense bamboo over twenty years old, and it was a difficult undertaking to bring this under cultivation, especially as it was necessary to change completely the whole drainage system. To date 170 acres of the 300 have been cleared and this area is being developed as a mixed farm. The remainder is still under bamboo.

On the arable side, the emphasis is on crops suited to the climate and soils of the area, but financial stringency has made it impossible to develop the research and investigational aspects as much as is desirable. A cash crop, sugarcane, therefore occupies the biggest area of the farm and by the middle of next year it is hoped to have nearly 90 acres under this crop. Work is also in progress on annual crops such as yams, corn, pigeon peas, &c., and a section has been devoted to citrus. Particular importance is attached to a market garden section, which has provision for overhead irrigation in the dry season. This undertaking is interesting in view of the great difficulties encountered in market gardening on a commercial scale in the wet tropics. The establishment of commercially successful undertakings of this nature are likely to become of great importance in colonial territories as development and the accompanying industrialisation and growth of urban centres proceed. The farm is well situated in this respect, being in the middle of a market garden area—albeit mostly on the peasant scale—serving Port-of-Spain.

Concurrently, improvements are being effected in the courses of instruction in agricultural engineering and farm mechanisation, and this has been much assisted by generous gifts from a number of manufacturers of agricultural tractors and machinery. There is now available for the teaching and application of farm mechanisation a wide range of tractors and implements, including wheel and track tractors and small units suitable for market garden cultivation.

Hitherto there have not been adequate facilities at the College on the animal husbandry side and a balanced section on animal husbandry is now being developed. At the time of writing there are 40 head of cattle in the dairy herd ; the cattle are grade Zebu-Holstein, the type of stock at present advocated by the Trinidad and Tobago Department of Agriculture. The future livestock policy with cattle will be to build up a herd of milking strain Sahiwal or Sindhi Zebus if funds can be found for the purchase of foundation stock. Representatives of the smaller livestock which are kept include British Alpine Goats, Black faced Persian sheep, large black and large white pigs, Rhode Island Red (Parmenter strain) poultry, and geese. Thus for

teaching and demonstration the Farm has a representative collection of the types of livestock which College students are likely to meet during their later careers.

Another aspect of the animal husbandry section is the study of problems connected with the economy and management of grasslands, for silage and for grazing, and the integration of crop and animal husbandry. The usual system of livestock management in Trinidad is to grow fodder and to cut and transport it to the cattle sheds and it is important to study the costs and effectiveness of this method compared with establishing suitable pastures, supplying fencing and water, &c. Work is in progress both to improve existing fodder and grazing grasses and on the introduction and testing of new fodder species.

The conception of a mixed farm on a relatively large scale, in contrast with the two extremes of permanent or semi-permanent tree and other "estate" crops, and small scale peasant agriculture, is a novel one under wet tropical conditions. There is a tremendous amount to be learned about the practicability and economics of this type of farming.

It is also hoped that it will soon be possible to acquire an area of hilly land, so that the agricultural management of slopes incorporating anti-erosion and soil conservation measures can be studied, taught and demonstrated. So far, however, financial difficulties have not permitted the acquisition of suitable land.

Progress so far has been encouraging but there is still much to be done and much to be learned. It is hoped that it will be possible to continue to develop the I.C.T.A. farm so that facilities will be fully adequate for teaching and research requirements.—A.B.K.

REVIEW ARTICLES, NOTES, AND BOOK REVIEWS

GENERAL AGRICULTURE

I.C.T.A. FARM FIELD DAYS

THE COLLEGE FARM was 'At Home' to visitors on the 24th and 25th April, 1952 on the occasion of the annual Farm Field Days. On the first day the Agricultural Society of Trinidad and Tobago held their monthly general meeting at the Farm and members of the Society were the guests of the College. There were numerous other visitors (attendance was estimated at 350) and the event was formally opened by His Excellency the Governor on the morning of the 24th April.

With the growing development of the Farm it was possible to widen the scope of the exhibits and demonstrations and the programme was a more ambitious one than in the preceding year when the first of these events was held. Exhibits and demonstrations embraced grazing and fodder grasses and pasture management, commercial market gardening (including overhead irrigation), tractor demonstrations, livestock exhibits, butter making and machine milking. There were, in addition, a number of static exhibits including poultry feeding and management, clean milk production and the keeping of livestock records.

Local Agricultural machinery agents co-operated to the full in making the Days a success and the participation of two distributors dealing in insecticides and stockfeeds added to the scope of the exhibits.

The following firms staged exhibits and gave tractor and machinery demonstrations in the field:

Trinidad Agencies Ltd.
Charles McEnearney & Co., Ltd.
Neal & Massy Engineering Co., Ltd.
Dearles Ltd.
Trinidad Trading Co.
T. Geddes Grant Ltd.
H. E. Robinson & Co., Ltd.
Government Marketing Board.

A.B.K.

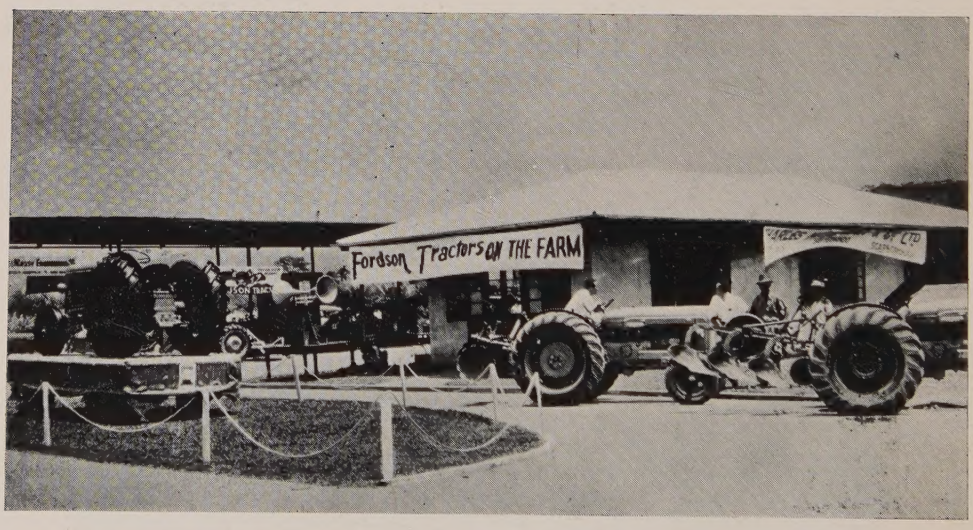
FARM FIELD DAYS

His Excellency addressing visitors at the opening of Field Day.

New Fordson Major tractor with T.V.O. engine towing two old type Fordson tractors during draw-bar tests.

FARM FIELD DAYS

Diploma students with Holstein heifer class



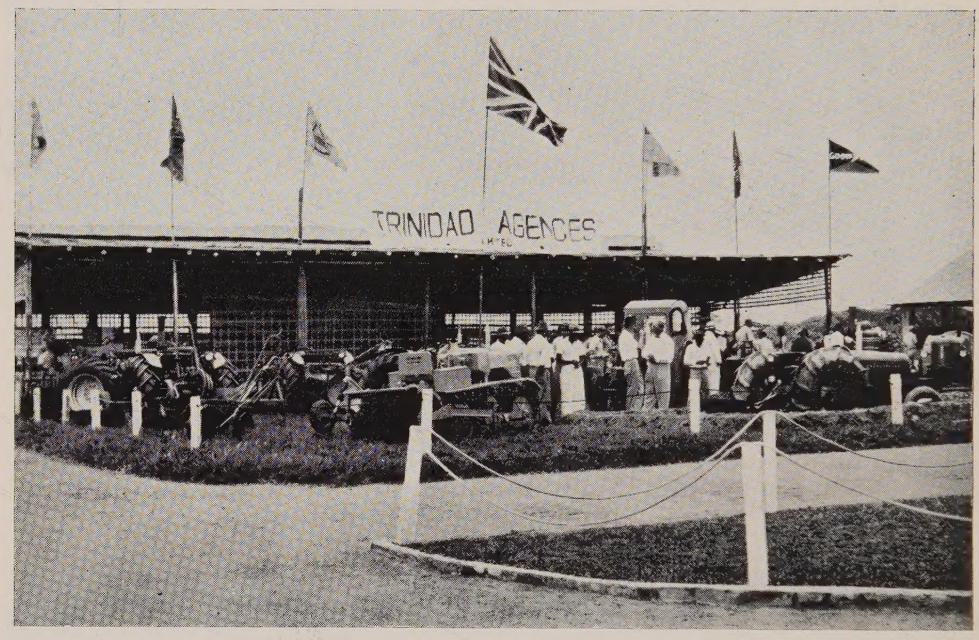
Charles McEnearney's stationary exhibit showing 3 new Fordson Major tractors. To one of the tractors is fitted a set of heavy mounted discs and to another a 3-furrow mouldboard plough.

FARM FIELD DAYS

Neal & Massy Engineering Co. stationary exhibit the day before the show—left to right :—
Ferguson with rear mounted mower attached.
Ferguson with rotary hoe attached.
Ferguson with sickle-brush-cutter.

H. E. Robinson & Co., Ltd., stationary exhibit showing two of the first shipment of International Farmall M. tractors received from the Factory in Great Britain. Standing between the tractors are a Rotary Hoe made by Howards of Australia, and Motor Scythe manufactured in Croyden by Mayfield Engineering Ltd.

FARM FIELD DAYS



A general view of Trinidad Agencies exhibit.

Digitized by the Internet Archive
in 2025

https://archive.org/details/tropical-agriculture_april-june-1952_29_4-6

Ferguson Tractors in the Cultivation of Rice.

THE USE OF FERGUSON TRACTORS IN THE CULTIVATION OF RICE

Ferguson tractors have recently been introduced to Trinidad and are causing considerable interest in agricultural circles. The Ferguson system of direct linkage of the implement to the tractor, weight and draught transference, and the general compactness of the design seem to suit local conditions surprisingly well. These photographs show a flooded rice padi being cultivated with the "bush-and-bog" harrow attachment (a two-way cutaway disc). The driving wheels of the tractor are fitted with wheel girdles.

Experience in Trinidad has shown that such equipment as this can work satisfactorily on flooded clays provided that free water covers the surface of the mud, and provided that a relatively firm bottom exists a few inches below the mud. These conditions are likely to exist in the wet season.—J.E.M.

DE LANDBOUW IN DE INDISCHE ARCHIPEL

(Agriculture in the Archipelago of the N. E. Indies)

A symposium edited by Dr. C. J. J. van Hall and C. van de Koppel with the collaboration of numerous other prominent experts on the various lines of Agriculture in pre-war Dutch East Indies. Published by Uitgevery W. van Hoeve,'s-Gravenhage, Netherlands. Four volumes, total pp. 2,740. *Ill. Price:* 100 *florins.*

This standard work presents an elaborate condensation of the knowledge and experience of the many Dutch scientists who devoted their skill and a lifetime's work to research and to the practical development of tropical agriculture in Indonesia.

The work was initiated by the publisher, W. van Hoeve, during the German occupation of Holland with the aid of experts in tropical agriculture who were there available. The documentation was finished around 1946, and included information and data obtained from experts who returned from the Indies after an imprisonment of many years by the Japanese occupation forces.

The basic idea and main purpose underlying this work was to create a unique and up-to-date record of all the knowledge gathered hitherto in the Indies, which might serve as an aid for the many young agriculturists who were supposed to reinforce the remnants of the " old guard " in Indonesia in an effort to build up and to restore what was destroyed in this war-ridden country.

This, perhaps, may account for the deplorable fact that the work was not written in English, which would have made it available to a far larger group of interested readers than it is now.

The work is divided into four volumes, I, IIa, IIb and III. Volume I is the general section; Volume IIa deals with food crops and medicinal plants; Volume IIb with luxury crops and spices and Volume III with Fibre-crops and other industrial crops.—H.S.

PLANT NUTRITION

A REVIEW OF RECENT INVESTIGATIONS ON CITRUS PRODUCTION, WITH PARTICULAR REFERENCE TO THE MINERAL NUTRITION OF THE CROP

BY

F. C. DARCEL

Introduction

Great importance is attached to the mineral nutrition of citrus. In recent years Florida has become one of the main citrus producing areas of the United States. Most of the soils used are very infertile sands; indeed citrus could not be grown at all without the use of mineral fertilizers. Again, much of the work on trace element deficiencies has been done on the citrus soils of Florida.

Some of the more important citrus soils in the United States are first briefly described, followed by a discussion of recent findings on the moisture requirement of the crop, and on diseases which are affected by soil conditions.

An account is given of recent research in various parts of the world on the various roles played by the major plant nutrients and the minor and trace elements.

Soils

The chemical characteristics of the Florida soils have been discussed in detail in one of the Agricultural Experiment Station Bulletins (33); some information on the common types of soil profiles is given below.

Citrus is largely grown on the well-drained upland soils; indeed, 70 per cent. of the total acreage in citrus is planted where the natural vegetation consists chiefly of long-leaf pine (*Pinus australis*) and oak (*Quercus* spp.) on the " high pinelands " of Central Florida. These soils have good natural drainage but very low natural fertility. The exchange capacity lies chiefly between 2 and 3 milli-equivalents per 100 grams, indicating a very low colloid content, most of which is provided by soil organic matter; an increase of 2.0 m.e. in exchange capacity per unit increase in the percentage of organic matter appears to be general.

One of the best soils is the Norfolk Fine Sand, hammock phase, the profile of which consists of 4 to 6 inches of yellowish-gray or gray sand above pale yellow or yellow sand to 2 to 20 feet above friable yellow to yellowish-red sandy clay. Similar textural features with fine sand above sandy-clay at variable depth characterize most of highly-rated upland soils of Florida. However, heaviest yields are obtained on rich alluvial soils.

The less satisfactory soils are imperfectly drained and are known variously as " low hammocks " and " palmetto flatwoods ". Slash pine (*P. palustris*), *P. caribaea*, various species of oak, hickory and cabbage palmetto (Sabal palmetto) are some of the more common species of the vegetation occurring on these soils.

Most profiles consist of gray to black topsoil changing through pale coloured sand or mottled sandy-clay to marl, usually within 3 feet from the surface. In some of the more poorly drained soils there is a dark brown or black organic hardpan below gray coloured topsoil at a depth of 12 to 30 inches; in others, the lower subsoil consists of gray and yellow mottled plastic, acid, sandy clay.

In California trials, medium-textured soils gave the highest yields, with the lowest on the lighter-textured soils (20). Indeed, it seems that citrus can be grown on any type of soil if managed correctly. However, gentle valley slopes are most suitable and areas of poor drainage and low topography should be avoided, particularly where there is a danger of frost (20).

Under good management, considerable attention is paid to soil acidity. The reaction should be maintained within the range pH 5.5-6.0 to keep the soil manganese, zinc and iron in available forms (5, 6, 33) and also to prevent magnesium deficiency symptoms, which commonly occur on the more alkaline soils through an excess of free lime. Magnesium deficiency often occurs in trees over " marl spots " in which marl occurs within 6 inches of the surface.

A suitable range of soil reaction is also beneficial by helping to maintain the nutrient status of the soil through the control of leaching. In one series of experiments repeated soil analyses during a period of one year indicated the conserving effect of maintaining a higher pH (5.7) on extractable calcium, magnesium, phosphorus and manganese as compared with areas receiving equivalent amounts of fertilizer but without pH control (pH values as low as 4.2). It was found that, although the pH level had no effect on extractable soil potash, the higher level increased the growth and production of grapefruit (39).

It is of interest to note the recent findings on the " citrus-sick " soils of Florida. The trouble is now attributed to an organic toxic material, produced by *Fusarium solani* and *Pyrenochaeta* spp., which gradually accumulates in citrus soils (25). Germination is seriously reduced and the seedlings suffer from root-tip damage.

Soil Moisture

An adequate water supply during crop growth is essential for maximum fruit production. In areas of deficient rainfall soil moisture can be conserved by planting the orchard on the contour with graded drainage banks (27) and by the use of mulch.

Premature defoliation is caused by severe moisture deficiency and is usually accompanied by leaf scorch through the toxic concentrations of salts. The condition is less likely on the deeper soils and in species which carry fruit all the year round (37). Corrective measures include increased frequency of irrigation, and the prevention of excessive leaching, salt accumulation or recurrent high water table under the trees by the use of improved irrigation furrows and soil drainage (37).

Irrigation is now widely practised, particularly under the dry climatic conditions of California. Care must be taken in its use, however.

Detailed studies of root distribution in citrus have shown that furrow irrigation is frequently wasteful and ineffective. Overhead irrigation which moistens the soil below the crown is markedly preferable, particularly in conjunction with cover cropping, mulching and the limitation of cultivation to the minimum (36).

The incidence of some root diseases becomes serious when the soil is over-irrigated. As an example, workers in the Transvaal have shown that the avoidance of soils in which moisture content is likely to become excessive by irrigation, and maintenance of a high nitrogen level, are effective in preventing and controlling dry root rot and diplodia gummosis (*Diplodia natalensis*) (24). The method of application of water is also important. In controlling brown rot gummosis (*Phytophthora citrophthora*), which is favoured by moist and cool conditions in Natal and the eastern Cape Province, irrigation water should be kept 2 feet away from contact with the barks by parallel ridges on either side of the trees (24).

Mineral Fertilizers

A number of fertilizer trials with citrus have recently been recorded. Leaf analysis, as a means of determining the nutritive condition of the plant at various stages of growth, is being increasingly used. Considerable fluctuations in the mineral content of the leaves have been noted. Nitrogen, phosphorus and potassium contents declined with age, calcium increased rapidly for 4 to 5 months and then remained constant and magnesium reached a peak in 5 to 6 months, dropping to a low level in old leaves (23).

A correct balance between the different fertilizers is essential. Indeed, a high content in the soil of any one base (e.g. calcium, magnesium), in relation to other bases, will inhibit the absorption and/or utilization within the plant of those bases present in lesser amounts (14).

The mineral status of the leaves can vary widely with the types and quantities of fertilizer used. The results of one experiment on these lines are given below.

On experimental plots, mainly of sandy loam, Eureka lemons showing symptoms of leaf spot on the older leaves were treated with 2.3 lb. of nitrogen per tree, alone or in combination with 9.6 lb. of phosphorus and/or 10 lb. of potassium. Significant response to phosphorus resulted in an increased phosphorus content from 0.08 per cent. to above 0.1 per cent. in recently matured leaves, and in higher yields. Treatment with potassium depressed yields, apparently by reducing the phosphorus and magnesium levels of the trees. The potassium content of young leaves in most cases was above 0.4 per cent., regardless of treatments, and the results indicated that spotted leaves were associated primarily with phosphorus deficiency, and that the composition of recently matured rather than spotted old leaves should be taken as an indication of the nutrient status of the crop (1).

In another experiment elimination of PK treatments caused a marked decrease in the phosphorus content throughout the tree and an increase in potassium and nitrogen in the leaves (41).

It has already been mentioned that citrus soils are generally of low fertility. The soils of Florida might again be mentioned as being little more than a rooting medium.

Fertilizer trials in Brazil may be noted (38). Degeneration of citrus after 10 years was attributed to soil exhaustion. Good responses were obtained with mineral fertilizers.

Some interesting work has recently been done on the utilisation and retention of fertilizers from different mixtures, using lysimeters. The utilization of fertilizers was found to be small, amounting to 20 per cent. for potassium, 10 per cent. for nitrogen and 7 per cent. for phosphorus. Lysimeter studies showed losses by leaching of 8.56 per cent. of potassium, 1.73 per cent. of nitrogen and 0.6 per cent. of phosphorus of the amounts applied (7).

Long-term lysimeter fertilizer trials are also being conducted on the Coastal Plains of Israel (41).

Nitrogen

Leaves of the orange suffering from nitrogen deficiency become pale to yellowish green, particularly in the veinal areas, and may eventually become completely yellow and finally shed. The growth is short and die-back of the twigs often occurs. The fruit is small, pale in colour and ripens prematurely (3).

The results of a number of fertilizer trials show that nitrogen is usually deficient except on the more highly organic soils, such as the Davie soil of Florida with 14 per cent. or more of organic matter (2).

Fertilizer experiments conducted over a period of 22 years with Washington Navel oranges on a soil classified as Ramona Loam gave marked yield responses from 3 lb. per tree of nitrogen applied in autumn, half as mineral fertilizer and half as manure. Increased dressings of nitrogen did not show any additional benefit, and continuous use, particularly of sodium nitrate or ammonium sulphate, adversely influenced soil structure and fruit yields. Excess of nitrogen was also found to cause thickening and softening of the fruit skins, and reduction in the powers of resistance of shoots to various diseases (38). The harmful effects of excess nitrogen can be minimized by gypsum, limestone, manure and cover cropping. Cover crops preceded by dressings of bulky organic materials were found to increase both fruit yields and size (3).

In trials with neglected orange trees grown on sandy soils in Palestine with 10-14 per cent. calcium carbonate, responses were obtained with annual applications of 1 kg. of ammonium sulphate per tree occasionally supplemented with 2 kg. of superphosphate. In some treatments the mineral nitrogen was supplemented with either dry manure, 15 kg. dry sheep manure or 3 to 5 kg. of cottonseed meal per tree; no responses were obtained with these additional treatments. Lopped trees appeared to have stored reserves of nitrogen. It was also found that " unbalanced " trees, those either heavily pruned or

unfertilized, produced larger fruits of poorer quality, similar in effect to the larger doses of cottonseed meal. Clean cultivation of groves seemed to be equivalent to applying nitrogen fertilizer (28).

In other experiments, the total yields and internal quality of grapefruit and orange supplied entirely with inorganic nitrogen appeared slightly better than those receiving 40 per cent. of the nitrogen in organic form, provided adequate magnesium, copper, zinc, and manganese were also added. It was recommended that, as the organic fertilizers often supply trace elements, they may be preferable to inorganic fertilizers when minor elements are not included (35).

Large nitrogen losses from citrus soils occur as the result of leaching and volatilization, a high content of phosphorus in the soil being thought to increase the loss by volatilization. Possible means of reducing these losses are suggested, including frequent applications of small doses of nitrogen to irrigation water, the use of low head sprinkler irrigation, non-cultivation, and making neutral and alkaline soils slightly more acid (9).

The soil nitrate content shows wide variations both from one sampling spot to the next and at different times of the year. In one investigation, nitrate levels in the top 30 cm. varied from 4 to 12 p.p.m.; values above 10 p.p.m. indicated adequate nitrogen nutrition. Twenty or more soil samples were required for an estimation of soil nitrates in a grove area of 2 dunams (2,000 sq. m.). Leaf analysis required 5 to 8 samples. Spring was found to be the most suitable season for soil sampling (19).

Phosphorus

Considerable work has also been done on the part played by phosphorus in the nutrition of the crop. Where phosphorus is deficient, the leaves of the orange are dark green with the older leaves faded green to bronze, with some areas "burned"; the older leaves are shed, there is some die-back and the fruits are few (3).

Oranges and lemons seem to require different quantities of phosphate. In one experiment, using different rates of application, a beneficial action of phosphorus occurred on lemon in the high range, but on orange only in the very low range of phosphorus concentration. Controlled experiments with artificial cultures also indicated the unequal phosphorus requirements of lemon and orange trees. With larger phosphorus concentrations it was relatively easy to maintain an adequate nitrogen supply for lemon, but not for orange cultures (17).

On the highly organic Davie soils, applications of phosphorus had a very decided effect on yield. Plots receiving no phosphorus gave the lowest production and the poorest quality fruit. On the other hand, high concentrations of phosphorus caused excessive fruit drop, ammoniation and other symptoms of copper deficiency (12). There does not seem to be any valid evidence that phosphorus depresses nitrogen absorption (10). Applications of phosphorus in excess of calculated uptake were in no way

harmful but improved the quality and reduced the maturation period of the fruit (38). Applications of treble superphosphate slightly increased the calcium and magnesium content of the plant but decreased the potash (23).

Experiments in Shamouti orange groves showed that phosphate varied from 12 to 93 p.p.m. in the top 60 cm. of soil. Application of superphosphate in solution increased the availability and percolation of phospate (19).

The effects of phosphorus were investigated over a period of 9 years on oranges, grown in out-of-door solution cultures at levels ranging from 2.5-3.5 to 150-175 p.p.m. of phosphorus. The results indicated that (*a*) low levels particularly affected the firmness of fruit and juice quality and made trees susceptible to "water spot" during cold spells, and (*b*) high levels encouraged pathogenic fungi and tended to aggravate zinc, manganese and iron deficiencies (10). Leaves from phosphorus deficient trees were high in nitrogen and potassium, but low in calcium.

The ideal phosphate status was tentatively given as 0.12-0.13 per cent. of total phosphorus in 5 to 8 months old spring-cycle leaves. As culture-solution levels of 2.5-3.5 p.p.m. of phosphorus proved insufficient, in contrast to earlier field observations, it is believed that citrus trees may, by their cyclically and slowly growing roots, utilize small quantities of soil phosphorus in fields where quick growing crops fail (10).

Gaarder (15) has shown that phosphate reverts to tricalcium phosphate only at high pH values. The process starts at about pH 5.5 but does not reach a maximum until pH approaches 7.5.

Accumulation of mono-calcium hydrogen phosphate in sandy soils of Central Florida is due to continual use of superphosphate and the adjustment of soil pH to 5.5-6.0 with ground limestone. The accumulation increases the retention of added sulphates of magnesium and manganese but not potassium chloride or sulphate. It also results in improved growth and yield of grapefruit (40).

Potassium

Potassium is also of great importance, particularly in relation to the quality of the fruit. In grapefruit, deficiency is shown by the die-back of the topmost leaves; the leaves are irregularly coloured, pale and bronzed; fruit production is small. In orange, the leaves show "fluting" or "tucking"; tiny germ spots enlarge, become roughened and dark coloured; the fruit is thick skinned, coarse and of poor colour with the juice low in acids and high in solids (3).

In long-term experiments it was found that the size, but not the number of fruits, was increased by potassium sulphate. Fruit size was correlated with potassium concentration and dry weight of leaves. Organic fertilizers produced similar results. Fruit size was not related to phosphorus, calcium or nitrogen concentrations (29). On an alluvial soil high in quartz sand (Ramona loam), trees receiving potassium sulphate produced a larger proportion of larger sized fruits, at least since 1939, of a very slightly

improved commercial grade; the potassium concentration in the leaves was the primary factor associated with size variations in the fruit (30). This finding is confirmed by other experiments (31). High quality fruit was produced by manuring with potassium carbonate and wood ashes (38).

The type of potash fertilizer does not seem to be important. Similar responses were obtained on fairly highly organic soil (Davie soils—Florida) with either the chloride, sulphate or carbonate (12).

The absorption of potassium by the plant is affected by the quantity of calcium. Potassium replaces calcium on the soil colloids more readily than it does the hydrogen of acid soils; hence the efficiency of the soil colloids (the exchange complex) in absorbing potash from a fertilizer solution is increased in the more alkaline soils (33).

Foliar diagnosis is an important aid in determining the fertilizer requirement of the crop. The ratio, in equivalents, of calcium plus magnesium to potassium per unit of dry weight, was much modified by fertilizing practices and increased steadily with age. These changes in composition must therefore be taken into account in the interpretation of the analyses (23).

Soil tests for potash may be somewhat misleading owing to the deep rooting habit of the plant in good structured soils, as in an investigation reported from Brazil (38).

Excess potash manuring should also be avoided. An unpleasant salty taste persisted in fruit of orange trees 3 to 5 years after applying potassium chloride in an unbalanced fertilizer mixture. It was concluded that on this particular soil, phosphorus was the limiting factor (38).

Although potash influences fruit quality, it is worth while mentioning the effect of the time of picking. Under normal conditions the quality of the fruit at the time of harvest is of prime importance. The quality of the fruit is affected both by the stage of ripeness at which it is picked and by the mineral nutrition of the parent crop.

As a general principle, the crop should not be harvested until the fruit is mature. Fruits picked before they have become mature neither contain their potential maximum of sugars nor do they develop any more sugars after picking. In one investigation in which 13,000 individual fruits were examined, it was found that the volume of the juice and total solids increased and the acidity decreased as the fruit ripened, in both large and small fruits. Other factors with a bearing on fruit quality were the species and variety of tree, the amount and type of fertilizer, drought, drainage, irrigation, insects, pests, diseases and " freezes ". (18).

Trace Elements

It has already been noted that citrus is widely grown on sandy soils of low fertility. Both the major and minor plant nutrients are usually lacking.

Magnesium, manganese, zinc and copper have received the greatest attention over recent periods. Boron is also an essential nutrient.

Magnesium: By making a study of the chemical composition of fruit and foliage, Fudge has shown that " bronzing " of citrus is definitely associated with magnesium deficiency (13).

The deficiency symptoms often occur on calcareous soils as in Florida with an adverse calcium to magnesium ratio. For full utilization of the magnesium, this ratio should be 8–10 : 1 (33). The use of magnesium sprays is now almost general practice in some parts of Florida.

There appear to be three types of chlorosis associated with the deficiency. " Older leaves chlorotic; type A, loss of chlorophyll in small patches along midrib fading to yellow and spreading outward until entire leaf yellows; type B varies from A wherein tip and base of leaf are green; type C more typical of magnesium deficiency in other plants in that chlorosis begins at leaf tip with green portions of leaf resembling American holly leaf; this last type is usually manifested by older leaves, whereas other forms appear to be associated with fruit maturation, affected leaves usually shed ; seedless varieties less affected than those containing seed " (3).

Manganese: The usual symptoms of deficiency on the orange have been described as: " Young leaves show a network of green veins on a lighter green background ; in severe cases entire leaf assumes dull yellowish green followed by shedding; sometimes brown specks distributed over the leaf; twig growth reduced; fruit poor colour ". (3).

The deficiency trouble is widespread in Florida, occurring on both acid and alkaline soils throughout the growing areas (5). Zinc and manganese deficiency symptoms are associated with " marl spots " in the cabbage-palmetto hammock soils where marl occurs within 6 inches of the surface (33).

Zinc: The " frenching " of Florida or " mottle-leaf " of California is caused by zinc deficiency (3). The leaves are chlorotic with irregular green bands along the midribs and lateral veins; the twigs tend to die back and the fruit quality and quantity may be affected according to the severity of the disease (3).

Zinc sprays are satisfactory as a control measure. Soil applications are usually unsatisfactory partly due to the poor root systems of affected trees (8) but also through fixation in the soil.

In Florida " frenching " of citrus occurs most commonly on acid sandy soils below pH 5.0, very low in exchange capacity, as well as on calcareous or over-limed soils. It appears that in acid sandy soils most of the zinc reserves are depleted by leaching, but are fixed in unavailable forms in the more alkaline soils (6). Over-liming may be the cause of " frenching "; trees growing on calcareous soils are frequently affected. There is some fixation of both copper and zinc in non-exchangeable forms in light sandy soils by the soil organic matter (21, 22).

Symptoms often occur when deficiencies of the major elements are corrected. In one manurial experiment, higher levels of nitrogen and potassium increased yields and gradually decreased the zinc concentration of the leaves, resulting in a mild deficiency after two years of treatment (34).

Copper: Copper and zinc deficiencies often occur together. The symptoms are described thus :—" Terminal growth dies back (known as " die-back ") before discovery of cause of trouble; first evident as large dark green leaves on long, soft angular shoots, leaves commonly irregular in contour, usually with a bowing up of midrib; in acute cases heavy twigs having multiple buds put out a profusion of young soft shoots with small leaves which die back from tips with reddish excresences over large portion of bark ; twigs may droop to form " S " shape; fruits may be bumpy and covered with reddish brown excresences, with gum pockets, may split; juice low in acid and pulp ; dries out early in season; roots may show gumming " (3).

Iron: Iron deficiency also occurs occasionally. " Terminal leaves chlorotic between veins at first; leaves thin ; in severe cases entire leaf becomes yellowish to orange, may show necrosis, at which time leaves shed beginning at terminals ; fruit sparse, small, hard, coarse, and light in colour ".

Boron: Boron deficiency is occasionally reported. " Young leaves develop small water-soaked areas which become spots on older leaves; veins show splitting and corking on upper surfaces ; leaves rolled from tips towards bases, brownish yellow colour ; shedding takes place from top leaves downward ; fruit brownish in white part of peel, gum forms, shape irregular " (3).

Summary

Some information is given on the type of soils on which citrus is grown, most of which are acid and sandy, with low natural fertility.

Overhead irrigation is becoming increasingly popular in the drier areas; some of the harmful effects of both drought and over-irrigation are discussed.

Large quantities of fertilizers are used in normal commercial practice. Trace element deficiencies are made good by applying sprays or by incorporating the deficient elements in the fertilizer mixtures.

The use of nitrogen fertilizers gives high yields of fruit of poor quality; potash on the other hand improves quality and size of the fruit but has little effect on the yield. Phosphorus is also of importance in yield production.

Some recent findings on the trace elements and their deficiency symptoms are briefly reviewed.

(1) Aldrich, D. G. and Coony, J. J. Lemon response to phosphate. *Calif. Agric.* 1951, **5**, No. 2, 5, 12; No. 3, 8. (Univ. Calif. Coll. Agric., Riverside). *Soils and Fert.* 1951, **14**, No. 3, Abs. 1190.

(2) The American Agricultural Chemical Company—Citrus Profiles, 1931.

(3) The American Potash Institute—Diagnostic Techniques for Soils and Crops.

(4) Baines, R. C. Nematodes on citrus. *Calif. Agric.* 1950, **4**, No. 8, 7. (Univ. Calif. Coll. Agric.). *Soils and Fert.* 1951, **14**, No. 2, Abs. 843.

(5) Camp, A. F. and Michael Peech. Manganese deficiency in citrus in Florida. *Proc. Amer. Soc. Hort. Sci.*, **36**: 81–85. 1938.

(6) Camp, A. F. and Walter Reuther. Studies on the effect of zinc and other unusual mineral supplements on the growth of horticultural crops. *Fla. Agr. Expt. Sta. Ann. Rept.* 1937: 132–135. 1937.

(7) Carrante, V., Di Prima, S. and Bottari, V. Terzo contributo alle esperienze permanenti di concimazione degli agrumi. (Triennio 1947–1949). Third contribution concerning the permanent fertilizer experiments on citrus. (3-year period 1947–1949). *Ann. Sper. Agrar. Roma* 1951, **5** (n.s.), 679–720. *Soils and Fert.* 1951, **14**, No. 6, Abs. 2289.

(8) Chandler, W. H. Zinc as a nutrient for plants. *Bot. Gaz.* 98 (4): 625–646. 1937.

(9) Chapman, H. D. Nitrogen needs of citrus. *Calif. Agric.* 1951, **5**, No. 6, 6. (Univ. Calif. Coll. Agric., Riverside). *Soils and Fert.* 1951, **14**, 5, Abs. 1934.

(10) Chapman, H. D. and Rayner, D. S. Effect of various maintained levels of phosphate on the growth, yield, composition and quality of Washington Navel oranges. *Hilgardia* 1951, **20**, 325–358. (Calif. Citrus Expt. Sta., Riverside). *Soils and Fert.* 1951, **14**, No. 5, Abs. 1937.

(11) F. A. O. Agricultural Studies No. 9, 1949—Efficient Use of Fertilizers.

(12) Forsee, W. T., Jr. and Young, T. W., Report on fertilizer experiments in an orange grove in the eastern Everglades. 1949. *Citrus Ind.* **30**, No. 7, 15, 18; No. 8, 11–12. C.A. 44 (8581). *Soils and Fert.* 1951, **14**, No. 1, Abs. 374.

(13) Fudge, B. R. Relation of magnesium deficiency in grapefruit leaves to yield and chemical composition of fruit. *Fla. Agr. Exp. Sta. Bul.* 331: 1–36. 1939.

(14) Fudge, B. R. The mineral composition of citrus juice as influenced by soil treatment. *Proc. Fla. State Hort. Soc.* **54**, 4–12, 1941.

(15) Gaarder, Torbjorn. Die bindung der Phosphorsaure in Erdboden Vestlandets Forst. Forsoks-Sta. *Meddel.* **14.** 1930.

(16) Haas, A. R. C. Fertilizer distribution and citrus-tree growth. *Calif. Citrog.* 1950, **35**, 136–137, 166–167. *C.A.* 44 (8581). (Univ. Calif. Citrus Expt. Sta., Riverside). *Soils and Fert.* 1951, **14**, No. 1, Abs. 372.

(17) Haas, A. R. C. Growth response of lemon and orange trees to phosphate. *Calif. Citrog.* 1951, **36**, 137, 166. Biol A. 25 (21436). (Univ. Calif., Riverside). *Soils and Fert.* 1951, **14**, No. 6, Abs. 2290.

(18) Harding, P. L. Citrus at its Best. Science in Farming, *Yearbook of Agriculture* 1943–1947. pp. 858–863.

(19) Heymann-Herschberg, L. Soils and leaf analyses as indicators of fertilizer requirements in Shamouti orange groves. *Ktavim*, 1950, **1**, 25–26. *Soils and Fert.* 1951, **14**, 5, Abs. 1935.

(20) Imperial Bureau of Soil Science, Tech. Comm. No. 34, 1936 (4) Citrus. P.27.

(21) Jamison, Vernon C. Adsorption and fixation of copper in some sandy soils of central Florida. *Soil. Sci.* **53** : 287–297. 1942.

(22) Jamison, Vernon C. The effect of particle size of copper-and-zinc-source materials and of excessive phosphates upon the solubility of copper and zinc in Norfolk fine sand. *Proc. Soil Sci. Soc. Amer.* **8** : 323–326. 1943.

(23) Jones, W. W. and Parker, E. R. Seasonal variations in mineral composition of orange leaves as influenced by fertilizer practices. *Proc. Amer. Soc. Hort. Sci.* 1950, **55**, 92–100. (Citrus Expt. Sta., Riverside, Calif.) *Soils and Fert.* **14**, No. 3, Abs.1185.

(24) Loest, F. C. Orchard practices in relation to " collar rot " of citrus. *Fmg. S. Afr.* 1950, **25**, 331–333, 340. *Soils and Fert.* 1951, **14**, No. 2, Abs. 844.

(25) Martin, J. P. Effect of soil fungi on germination of sweet orange seeds and development of the young seedlings. *Proc. Soil Sci. Soc. Amer.* 1949, **14**, 184–188, *Soils and Fert.* 1951, **14**, No. 4, Abs. 1562.

(26) Martin, J. P. Seedlings on old citrus soils. Effect of water, acid, alkali and alcohol leaching of old citrus soils on growth of citrus seedling. *Calif. Agric.* 1950. **4,** No. 12, 3, 11. *Soils and Fert.* 1951, **14,** No. 2, Abs. 841.

(27) McGillivray, K. D. Contour planting on Central Coast citrus orchards. *Agric. Gaz. N.S.W.* 1950, **61,** 281–287, 357–360, 414–423, 457–460, 462. *Soils and Fert.* 1951, **14,** No. 2, Abs. 842.

(28) Oppenheimer, H. R. Studies on the re-establishment of citrus groves during the second world war. *Rehovot Agric. Res. Sta. Bull.* 1950, **54,** 55 23. *Soils and Fert.* 1951, **14,** No. 3, Abs. 1187.

(29) Parker, E. R. and Jones, W. W. Potash and larger oranges. *Citrus Leaves* 1950, **30,** No. 4, 6–7. C.A. 44 (8581). *Soils and Fert.* 1951, **14,** No. 1, Abs. 375.

(30) Parker, E. R. and Jones, W. W. Orange fruit sizes in relation to potassium fertilization in a long-term experiment in California. *Proc. Amer. Soc. Hort. Sci.* 1950, **55,** 101–113. *Soils and Fert.* 1951, **14,** No. 3, Abs. 1186.

(31) Parker, E. R. and Jones, W. W. Effects of fertilizers upon the yields, size and quality of orange fruits. *Calif. Agric. Expt. Sta. Bull.* 1951, **722,** p. 57. *Soils and Fert.* 1952, **15,** No. 1, 372.

(32) Peech, Michael. Availability of ions in light sandy soils as affected by soil reaction. *Soil Sci.* 51: 473–486. 1941.

(33) Peech, Michael. Chemical studies on Soils from Florida. *Citrus Groves Flo. Agric. Expt. Sta.* 1948, Bull. 448.

(34) Reuther, W. and Smith, P. F. A preliminary report on the relation of nitrogen, potassium, and magnesium fertilization to yield, leaf composition, and the incidence of zinc deficiency in oranges. *Proc. Amer. Soc. Hort. Sci.* 1950, **56,** 27–33. *Soils and Fert.* 1952, **15,** No. 1, Abs. 373.

(35) Sites, J. W. Present status of organic versus inorganic nitrogen as related to yield and fruit quality. *Citrus Ind.* 1950, **31,** No. 7, 10–13, 16. *C.A.* 45 (797). *Soils and Fert.* 1951, **14,** No. 3, Abs. 1188.

(36) Spurling, M. B. Water requirements of citrus. Part I. Citrus root Distribution. *J. Dept. Agric. S. Aust.* 1950, **53,** 536–541. *Soils and Fert.* 1951, **14,** No. 1, Abs. 373.

(37) Spurling, M. B. Water requirements of citrus, III. Citrus leaf drop. *J. Dept. Agric. S. Aust.* 1950, **54,** 190–194. *Soils and Fert.* 1951, **14,** No. 3, 1189.

(38) Vasconcellos, P. W. C. de. Algunas observacoes sobre adubacoes de citrus. (Some observations on fertilizers for citrus). *An. Esc. Sup. Agric.* " Luiz de Queiroz ", Univ. Sao Paulo 1949, **6,** 13–22. *Soils and Fert.* 1951, **14,** No. 4, Abs. 1560.

(39) Wander, I. W. Importance of pH control of soil in citrus groves. *Citrus Mag.* 1950, **12,** 30–33. *Soils and Fert.* 1951, **14,** No. 3, Abs. 1184.

(40) Wander, I. W. The effect of calcium phosphate accumulation in sandy soil on the retention of magnesium and manganese and the resultant effect on the growth and production of grapefruit. *Proc. Amer. Soc. Hort. Sci.* 1950, **55,** 81–91, *Soils and Fert.* 1952, **15,** No. 1, Abs. 374.

(41) Winnik, M. Some effects of P and K deficiencies on orange tree growth, composition and fruit quality. *Trans. Fourth Internat. Cong. Soil Sci.* 1950, **1,** 240–242. *Soils and Fert.* 1951, **14,** No. 1, Abs. 376.

(*Received for publication, June,* 1952)

PLANT DISEASES

DISEASE IN PLANTS

By N. E. & R. B. Stevens. *Waltham, Mass.—The Chronica Botanica Co.; London, W.C. 2—Wm. Dawson & Sons, Ltd.* 1952, pp. 219. Price $4.75 (U.S.).

"Of making many books there is no end....."

(*Ecclesiastes* 12: 12).

This quotation, with which the junior author opens his Preface, is certainly applicable to the publication of works in the field of Plant Pathology during the past few years! Nevertheless, the volume (the first of a proposed series of 12 comprising a "Manual of the Plant Sciences"), does usefully present the subject from a rather different angle. It deals in some detail with general aspects, devoting little space to individual diseases, and then only to illustrate principles.

The chapters devoted to causal agents are concise; justifiably so, since full up-to-date accounts are available elsewhere. Condensation seems to have led, however, in at least one instance, to some obscurity: the final paragraph under the heading "Multiplication of Viruses" does not logically follow on from the penultimate one as it purports. Surely, too, the accumulation of toxic waste products is at least as potent a factor as food supply in limiting bacterial populations? The later sections on "Factors Influencing the Development of Pathogenic Diseases" and "Disease Control" provide a vast amount of useful and interesting information. The writers' approach to control measures is essentially sound and realistic.

The book contains a large number of excellent plates and diagrams. It fully maintains the high standard of production we have come to expect from Dr. Frans Verdoorn and the Chronica Botanica Co.—W.T.D.

:: :: ::

ECONOMICS AND STATISTICS

DEVELOPMENT AND WELFARE IN THE WEST INDIES

Advocate Co. Ltd., Barbados. 1951. *pp.* 114—*Price*: 3*s.* 4*d.*

This report follows the lines of its admirable predecessors. It is a compact, well-produced booklet that does credit both to the Hastings House Staff and to the West Indian printer and binder. The statistics at the end of the report give a comprehensive summary on Development and Welfare Activities. —A.L.J.

AN ECONOMIC SURVEY OF THE COLONIAL TERRITORIES

Volume III—*The West African Territories*. 1951. *pp.* 103—*Price* : £1 5*s.*

This report is the third of the post war series of Economic Surveys. The surveys fall mid-way between the popular Colonial Annual Reports and the less popular Colonial Blue Books. They present wealth of up to date factual information in very readable form. Two surprises in this volume are the price, which hardly encourages purchase by the private individual, and the column arrangement of the text which is not consistent and may misdirect the unwary reader from say diamonds to bauxite.—A.L.J.

:: :: ::

STATISTICS FOR COLONIAL AGRICULTURE: REPORT ON THE ORGANISATION OF RECORDING AND ESTIMATING

By K. E. Hunt. *Colonial Research Publication No.* 11. *H.M.S.O.* 1952. *Pp.* 84

Technical advice on statistical methods is theoretically available to an increasing number of colonies as statistical departments are established. It may be thought therefore that this book is at least ten years after its time. It most certainly is not. Few Government statisticians have time to organise and supervise special agricultural enquiries themselves and even fewer have time to carry out the often essential preliminary step of convincing agricultural officers that such enquiries are both necessary and practicable. This book should serve the latter purpose admirably. It covers the whole field from line and area surveys to marketing and distribution studies without one intimidating statistical formula. It explains sound field procedures in a commonsense manner and faces up squarely to the perennial stumbling blocks of mixed cropping, shifting cultivation, continuous harvesting, &c.

A justifiable addition to this book would be an expanded preface to emphasise the dearth and value of survey data. Administrative and agricultural policy in many colonies is still based primarily on customs' returns and a decennial census of population. It is important at the outset for the agriculturist to realise that without survey data he is in about the same position as a chemist with no calibrations on his laboratory equipment; he may advise a pinch of this or further investigation of that but has little factual evidence to guide him—A.L.J.

COMMUNICATIONS ON ORIGINAL INVESTIGATIONS

A RECONNAISSANCE OF THE AMERICAN OIL PALM

Elaeis melanococca (Gaertner (em. Bailey) = *Corozo oleifera* (Giseke) *Alfonsia oleifera* (H.B.K.)

By

S. de BLANK

Whether the American oil palm is to be placed in the genus Corozo or Elaeis has not been finally determined. The name *E. melanococca* is used here as it probably is more generally known to agriculturists.

Introduction

Increased interest has been shown in this American oil palm in recent years, partly as a result of the attention drawn to it by L. H. Bailey, and partly as a result of a trial planting established by the Institute National de l'Etude Agronomique du Congo Belge at Yangambi, Belgian Congo in 1940 and 1941 (from seed collected from four specimens considered to be *Elaeis melanococca* palms growing in the Botanical Gardens at Eala near Coquilhatville, Belgian Congo). The origin of these palms is not quite certain but they probably originated from seed imported from Belem, Para, Brazil over 20 years ago (private communication).

The main commercial interest of this species lies (*a*) in the accessibility of the fruit due to the partly procumbent habit of the trunk and (*b*) the high oil to bunch ratio, this being attributed to the large proportion of parthenocarpic fruits (private communication). The possession of these characters opens up two lines of enquiry: first, the possibility of using this species as a plantation crop and second the possibility of introducing these characters by hybridisation into the African oil palm, *Elaeis guineensis* Jacq. A palm of low stature making possible a simplification of harvesting procedure would evidently be highly advantageous.

Considerable interest was shown in this palm at the Oil Palm Conference held at Benin, Nigeria in December, 1949. Since then the writer has had the opportunity of visiting S. America (Jan.-June, 1950) and of making a general reconnaissance of *Elaeis melanococca* over a considerable range of territory. This involved a journey of some 11,000 miles in S. America but the survey of the habitat of *Elaeis melanococca* was far from complete,—an indication of the time that would be required to carry out a full botanical survey. The claim may perhaps be made that many of the characteristic habitats were inspected.

E. melanococca was observed in the following territories:—Brazil, Canal Zone, Panama, Costa Rica, Colombia and Surinam. Venezuela was not visited as although Bailey has reported its presence in that territory (Bailey, L. H., Gentes Herbarum III. pages 56–62, 1935), it was not observed by the F.A.O. Oil Seeds Mission which visited Venezuela in 1938 (report F.A.O. Oil Seeds Mission for Venezuela, March 1940, Washington.)

Information on the American oil palm, largely based on the materials available for study in the Belgian Congo, is set out in an INEAC publication (série Scientifique No. 42, 1949 by R. Vanderweyen and O. Roels). This suggests that it is generally a denizen of marsh or marginal marsh conditions, has a procumbent trunk with an erect portion carrying the foliage and the fruit. The shell of the kernel is generally black from which characteristic the palm undoubtedly derived its name. In this publication it is also suggested that, as with the African oil palm, *Elaeis melanococca* may show a wide range of types similar to *dura*, *tenera*, *pisifera* in its wide-spread habitat. As will be seen, some of these conceptions are not supported by the data recorded below.

In the following notes the characteristic features of this palm in the various territories visited are described.

Botanical Characteristics of *E. melanococca*

(*i*) *The Procumbent Trunk*

An outstanding feature in adult specimens is the procumbent trunk, the distal region of which curves upwards. Seedlings, however, grow erect and the erect habit is apparently maintained for some twelve to fifteen years. Thereafter the palm slowly assumes a procumbent habit, the length of the procumbent portion varying with age and environmental conditions. The old leaf-bases are shed at intervals as in other palms. At ground level the trunk is of small diameter but broadens considerably in the erect foliage-bearing portion. The latter varies in height according to the age of the palms but seldom exceeds two metres.

Among any considerable *E. melanococca* population, rare cases of palms are encountered which have retained the erect habit throughout. These palms appear to grow very slowly and are characterised by a massive trunk and early denudation of leaf-bases.

Procumbency is not directly due to soil conditions, nor to swampy or marshy conditions, as has frequently been suggested; indeed, palms growing in wet although not necessarily swampy conditions are more apt to be erect than procumbent.

(*ii*) *The Frond*

The frond of *Elaeis melanococca* is one of its most striking characteristics and is usually sufficient to distinguish it from the African oil palm. In the latter, the pinnae are more or less alternate and slightly inclined

on the main rachis so that they form a valley; in *E. melanococca* the pinnae are more or less opposite and set on the plane of the rachis so that the whole leaf is relatively flat. The spines at the base of the pinnae are very small, approximately 2-3 mms. in length. (On one site on the Rio Madeira, frond formation of all palms approximated more closely to that of *E. guineensis*, although in all other respects these palms had the typical characters of *E. melanococca*).

(*iii*) *Root formation in young palms*

In preliminary studies of rooting of the young seedlings and older palms with procumbent trunks, the following information was obtained. When the seed germinates a tap root with fine lateral rootlets develops; contemporaneously, the first young leaf appears. At the point of emergence of the primary root, secondary roots also grow out. At the two-leaf stage these roots continue to develop so that the tap root becomes relatively less prominent. This stage is followed by strong development of many main roots with abundant fine lateral rootlets. At approximately six months from germination, the base of the seedling becomes bulbous. During the first year, there is evidence of increasing development of the main downwardly directed roots, but after about two years, many new roots are emerging laterally from the bulbous basal region. A three-year-old palm thus shows copious root development all round its base. At the age of approximately seven years the main root development is seen to be about 20–25 cms. in depth, but with a considerable number of roots nearer the soil surface. Roots were traced to a distance of approximately three metres from the base of the palm. This is much less than has frequently been observed with *E. guineensis*. Roots, which seldom exceed one metre in length, are formed all along the length of the procumbent trunk, although the maximum number occurs at the point of emergence of the trunk from the soil. Observations on root development on a variety of soil types are in general accord with the above description.

(*iv*) *The Male Inflorescence*

Formation and development of the male inflorescence appears to be very similar to that of *E. guineensis*. The staminate fingers are arranged in an ascending spiral on the main axis of the inflorescence and pressed together to form an erect compact mass, ovoid in shape, the whole being enveloped in a thick fibrous spathe. As maturity is reached the peduncle elongates, the spathe is ruptured and the inflorescence eventually emerges completely from it. During and after pollen liberation, the peduncle continues to elongate, the ageing inflorescence assumes a more open appearance, and finally assumes the untidy drooping appearance already familiar in *E. guineensis*. The number of spikelets per male inflorescence varies considerably but averages of 91 and 114 were determined in two different regions. Individual spikelets vary from 4-16 cms. in length.

(*v*) *The Female Inflorescence*

The most striking feature of the female inflorescence is the persistence of the spathe. At first this is hard and presents a solid appearance until the emergence of the inflorescence. It then ruptures into a tangled mass of fibres which persists almost indefinitely, masking the floral spikelets and developing fruits. Even when the latter are mature the spathe generally persists. The persistence of this spathe has raised the question of how fertilisation takes place. To those who have had an opportunity of observing it, it is hard to believe that wind can be the main pollinating agent as is generally considered to be the case with the African oil palm. The presence of large numbers of small bees around the male inflorescence at the time of maturity and the fact that many emerge when the spathe is disturbed suggest that these may be the pollinating agents. Considerable numbers of small beetles were also observed in the inflorescence.

The inflorescence is composed of spikelets each ending in a short, broad-based spine, smaller than that usually encountered with *E. guineensis* and varying in length from 2–4 cms. and approximately 1–5 cms. in breadth. The number of spikelets varied from 91 to nearly 200 with averages in two districts of **124** and **167**. The average number of flowers was 25–27 per spikelet with a range of from 7–39.

A striking range of maturation can be observed within the bunch. Thus, whereas fully ripe fruits were present at the base of the bunch the flowers at the apex had only just been pollinated or the fruits were still in the early stages of development.

Hermaphrodite inflorescences were fairly frequently observed.

(*vi*) *Bunch and Fruit characteristics*

As the number of flowers of the female inflorescence is generally considered to exceed that found in *E. guineensis*, the formation of large bunches is to be expected. This has not, in fact, been borne out by observations of *E. melanococca* in Brazil. Bunches are usually small and even mature palms growing under apparently good conditions rarely carry any weighing more than 15–20 kilos. In any mature bunch, the large proportion of parthenocarpic and abortive fruits is a striking feature. Considerable difficulty was experienced on occasion in finding mature bunches. This, together with the gradation in maturation, made it impossible to carry out detailed observations of bunch and fruit characteristics such as percentages of various kinds of fruit, outer, inner, parthenocarpic, percentage pericarp, ratio oil to bunch &c. Palms growing in the open or under light bush were more productive than those under heavy bush or light forest; under heavy forest production was almost nil. Under good conditions palms may carry up to 18 bunches but this is exceptional and the average would be in the region of five. No information was obtained on the periodicity of production.

The individual fruits are much smaller than those of *E. guineensis*. A characteristic feature is that the calyx adheres to the fruit at maturity. The pericarp is usually thin, seldom exceeding 2 mm. in thickness although exceptional cases were encountered where it attained to 4 mm. and once even 5 mm. The shell is fairly uniform, varying from 1–3 mm. in thickness but seldom exceeding 2 mm.; the kernels are very small. In Brazil the black colour of the shell, a feature from which the palm derives its specific name, was not so evident that it could be called characteristic. In a number of cases, the shell was very dark in colour but it was not unusual to find more ordinary colours, ranging from light to dark brown.

The diversity of fruit types, such as is characteristic of *E. guineensis* in Africa, i.e. *dura*, *tenera*, *pisifera* &c. has not been realised in *E. melanococca*. There does not, for instance, appear to be any clear dividing line between the equivalent of the *dura* and *tenera* forms as has been suggested for *E. guineensis* by Vanderweyen; nor was I able on any occasion to observe the outer ring of fibres which is suggested as being the final determining factor in differentiating between the *dura* and *tenera* forms. It should be added that this characteristic for *E. guineensis* is determined only in the first fruit bunches produced in any one fruiting cycle. In the course of my reconnaissance of *E. melanococca* there was no opportunity in the time available to be able to ascertain whether any of the palms observed were starting a fruiting cycle. A *pisifera* form of *E. melanococca* was never encountered, although I was informed that this type exists, information that should, perhaps, be treated with some reserve.

The average weight of individual fruits varies between 8.5 and 12.6 grams.

As regards colour, there appear to be two main types of fruit. The predominant type, representing approximately 98 per cent. of the *E. melanococca* encountered, produces orange coloured fruits at maturity. The young fruits are light canary-yellow in colour, with a pale yellow or ivory coloured pericarp. After about the fourth month, they begin to assume a light orange colour which intensifies with approaching maturity and finally the whole fruit becomes orange in colour. The second type is also bright yellow during the early stages, but this coloration persists throughout the process of maturation and at full maturity there is no or only very slight, intensification of this colour. The two types are well known to the local inhabitants in certain regions of the Amazon and the latter was encountered principally on the Rio Negre. Nowhere during my survey in South and Central America was *Elaeis melanococca* encountered which exhibited the phases of fruit coloration depicted by Vanderweyen. Even the final colour shown in his illustration is considerably darker than anything encountered in South America. This difference raises the question as to whether the *E. melanococca* at Yangambi are a true representative of the South American species (or

whether it is a *guineensis/melanococca* hybrid). The differences in fruit colour may, of course, be due to environmental conditions, a point which should be elucidated when the *E. melanococca* introduced into Africa from various South and Central American territories begin to fruit.

Nuts with two kernels are fairly frequently encountered and on occasions nuts with three kernels have been observed. These observations extend Bailey's statement that nuts with single kernels are characteristic of *E. melanococca*.

(*vii*) *Varieties of E. melanococca*

Various authors have suggested that a range of varieties of *E. melanococca* comparable with those known in *E. guineensis* may exist. The evidence of this investigation does not support this view. The habit of growth, frond formation, inflorescence and fruit characteristics are of a relatively high order or uniformity over wide areas.

Observations on *E. Melanococca* in various regions

A. Brazil. In this country the palm is known as Caiaue or Dende do Para. Apart from the few poorly developed and almost uncared for specimens in the Botanical Gardens at Belem do Para, the palm is generally said to occur to the west of Itacoatiara, some 1,100 kilometres from the mouth of the Amazon River, a statement which was confirmed. Thus, *E. melanococca* was observed in the regions of Rio Negre, Rio Urubu, Rio Madeira and Rio Solimoes. From the distribution of the palm in these regions it must be considered doubtful whether it is truly indigenous therein. On the contrary the facts set out below suggest that it has been introduced from the west by migrant Indians:

(i) *E. melanococca* is generally found in small clumps varying in number from 15 palms to areas covering a few acres. The palms have not been observed as isolated specimens scattered throughout the forest and clearings as have other palm species such as *Astrocaryum*, *Oenocarpus*, *Bactris*, &c.

(ii) It is generally found on the " terra preta " or areas of good soil on high land adjacent to rivers; on only two occasions has it been found growing in low-lying areas adjoining the river subject to occasional flooding. In only one instance has it been observed as a denizen of true swamp or swampy, marshy conditions.

(iii) The available literature suggests that it must formerly have been present in considerably larger numbers than now. Except for one or two smaller areas where use is made of the fruit for feeding pigs and chickens, my own observations suggest that this species is gradually disappearing.

(iv) In Brazil these palms are almost invariably found in association with considerable deposits of old broken pottery—i.e. on sites of former Indian settlements.

(v) The palms generally appear to be of much the same age, with little evidence of the ordinary age spread shown by a natural population. Spontaneous regeneration on any appreciable scale was only occasionally observed.

It is suggested that the palm was introduced into Brazil by Indians migrating from west to east partly as a result of the pressure on the land available for cultivation and partly in their search for forest produce i.e. waxes, nuts and rubber. In the Indian villages, two types of palm are habitually used for preparing beverages, one being the Caiaue or *E. melanococca* and the other Pupunha (*Guilielma sp.*). It seems not unlikely that in their migration, the Indians carried with them the seeds of these palms, to enable them to continue to enjoy the beverages prepared from them.

B. Canal Zone. *E. melanococca* was observed in several localities in this region. Small groups may be seen on high ground adjacent to the road leading from Tocumen Airport to Balboa, and Panama City. These were growing either in open pasture land or under fairly dense scrub. They were all erect and appeared to be very poorly developed but whether this was due to age or to the effects of the regular burning of the pasture land and the underbrush, it is impossible to say.

There is one specimen with magnificent trunk development in the Experimental Gardens at Pedro Miguel. It is reputed to be 20 years old. It was still erect and showed no tendency towards the assumption of the procumbent habit. The height of the trunk to the lowest inflorescence was **2.10** metres. The persistence of the old leaf bases on the trunk suggests that this palm may not be as old as it is reputed to be. It carried at least 35 fronds, the length of the lowest being 6.18 metres and having 103 pinnae on each side with an average width of 6.53 cms. Bunch fruit development was low, only two being in evidence, but male inflorescences were very abundant. The number and size of the male spikelets were far in excess of anything seen in Brazil or elsewhere; the general aspect of the inflorescence was somewhat different, the spikelets being much less tightly packed and assuming at an early stage in its development a generally untidy and drooping habit of the male inflorescence of *E. guineensis*.

The external aspect of the female inflorescences was not different from that generally observed, although it was noted that the persistence of the spathe round the developing fruit was less marked and the fruits were clearly visible at an early stage. The bunch itself was a blunt cone in shape, containing a very large number of small fruits, orange coloured at maturity, with a thin pericarp of approximately 1 mm. and a shell of 2–3 mm. The average weight of the bunches was estimated at approximately 30–35 kilos. thus considerably in excess of those generally encountered in Brazil.

Further small concentrations of these palms were observed in other districts of the Canal Zone growing under a variety of conditions, i.e. fairly

dense forest, in open savannah country or scattered along the bottom of a ravine subject to frequent flooding. All these palms were procumbent in habit, the longest trunk observed being no less than 9.18 metres and almost semi-circular in shape.

C. Costa Rica. *Elaeis melanococca* has been observed on the Pacific Coast growing under a wide range of conditions varying from open pasture land to swampy forest conditions. The species here appears in two main habits, common procumbent type as already described, and an erect type apparently showing no tendency to procumbency. Nearly all the *E. melanococca* observed were growing on land which either was, or still is, subject to flooding. The difference in the habit of growth cannot, therefore, be attributed primarily to environmental conditions.

Bunch formation was sharply conical and the enveloping spathe was much less persistent than that observed in Brazil. The very small fruits were bright yellow in the early stages, later turning orange with approaching maturity; all were of poor type, although rather wider variations than usual were observed, the pericarp varying in thickness from 1.25 mm. and shell from 1–3 mm. with a very small kernel. The outward appearance of the nut was very dark brown or black in colour.

Specimens of erect *E. melanococca* are generally encountered on areas once covered with fairly heavy forest inland from the Coastal mangrove swamp and subject to periodic flooding with brackish water. This does not appear to affect unfavourably the general development of the palms and many good specimens were encountered. Some had attained the height, to the lowest opened inflorescence, of 3 metres and more, so that harvesting of the bunches from the ground would no longer be feasible. It was not possible to obtain any indication of the age of these palms, but the trunks were devoid of leaf bases, suggesting a considerable age. The development of the trunk was massive. There was a profuse development of adventitious roots from the lower portion of the trunk, but none had developed sufficiently to penetrate the surface of the soil and all had become necrosed. Apart from these peculiarities these erect *E. melanococca* palms appear to be quite typical of the variety. These palms at present cover quite considerable areas, e.g. up to 200 acres, but many of them are now being felled to make room for Banana development. Further down the coast, areas of *E. melanococca* were encountered growing either in clear savannah or on the edge of the swampy forest. These were all of the typical procumbent type.

Not all the areas where *E. melanococca* is known to exist in Costa Rica were visited.

D. Colombia. *E. melanococca,* locally known as the Noli palm, chiefly occurs in the La Miel River region. This unfortunately could not be visited during my stay in Colombia. My observations, therefore, relate to those regions lying between Monteria and Corozal in the province of Bolivar, and were mainly confined to the areas of both banks of the river Sinu. This land is subject to periodic flooding, but it seldom persists for more than one to two weeks. One cannot thus speak of truly swamp conditions. The soils, varying from a black to a chocolate brown clay loam, are very fertile, as judged by the excellent crops of manioc, coffee and sesame which they support. The land formerly, undoubtedly carried light to medium forest, but this has now been largely cleared to make room for annual crop production. *E. melanococca* was growing chiefly in land cleared for pasture but was also observed growing under light scrub or in association with bananas and cacao.

Whether or not this palm species is truly indigenous in this area is difficult to decide, but if clearing operations continue at their present rate there is little doubt that it will virtually disappear in the near future.

The general aspect of the palm is quite typical but there is considerable variation in the habit of growth ranging from what appears to be quite old palms with an erect habit to those with the more usual procumbent habit with trunks varying from 3–6 metres along the ground. The erect types attain a quite considerable height and some showed 3.20 m. and over from the ground to the lowest inflorescence which would render harvesting from the ground impossible. The trunks were very large and generally clean, suggesting palms of a considerable age. In the procumbent type, the erect portion of the trunk appears to develop more strongly in height and some reached as much as 2.80 metres to the lowest inflorescence. Surprisingly enough, under these good conditions of growth, there was less frond development than in other territories, the average length amounting to 4.67 metres. The number of fronds per palm was, however, generally greater, rising in some cases to 37 and averaging around 31–32. The number of leaf pinnae varies from 71 to 103. Unfortunately the palms were observed during the period of lowest production, so that little can be said of their productivity. The fruit bunches soon had the typical conical shape seen generally outside Brazil and showed the maturation features already noted. In many cases, the lower portion of the spathe appeared to be more persistent than is the case in the Canal Zone and Costa Rica. Fruit type, form and coloration were in agreement with those seen in other territories.

This was the first territory visited in which an attempt is being made to utilise *E. melanococca* fruit for oil production, both pericarp and kernel oil being extracted by primitive means and sent to Medellin or Baranquilla where it is manufactured into soap and other products.

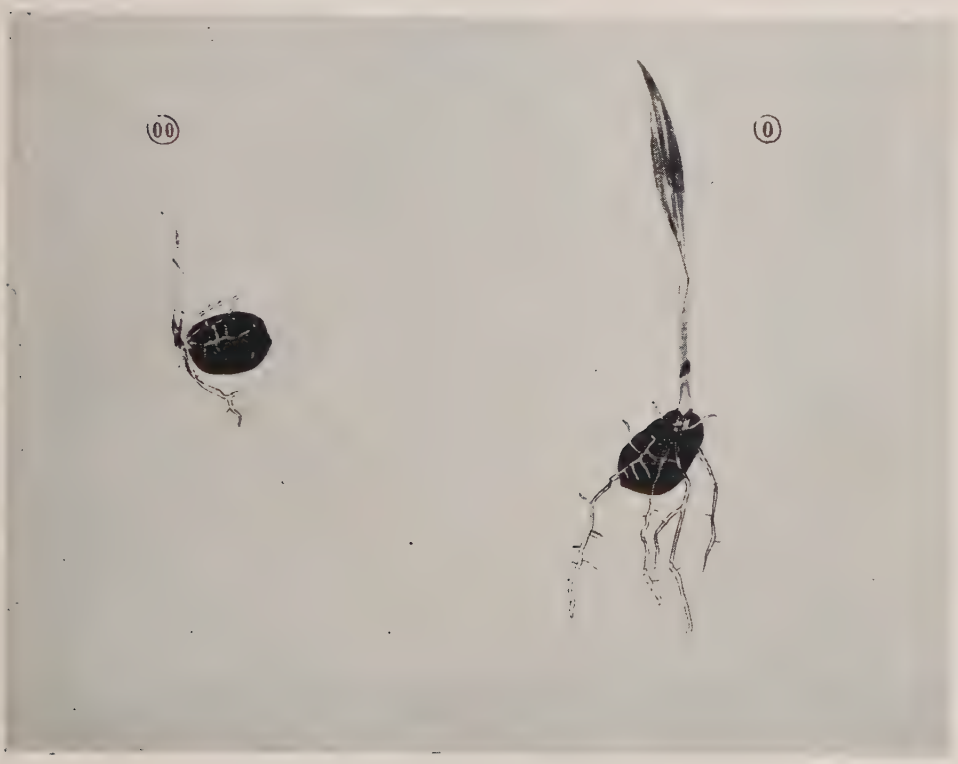
Fruit Bunches showing persistent spathe.

Hermaphrodite and Normal Bunch.

General aspect *E. melanococca* (Panama)

E. melanococca Palms (Colombia)

E. melanococca showing typical procumbent trunk (Brazil)



Germinated Seed

Root Development at one-leaf stage.

Root Development, Seedling approx. 6-months-old.

Root Development at two-leaf stage.

Root Development—18-month-old Seedling.

E. Surinam. *E. melanococca* in this territory is concentrated in a narrow belt of land where the coastal plains, as opposed to the coastal swamps, merge into savannah land. This belt is said to vary in depth from 35-40 kms. It consists of a rather poor sandy soil and the vegetation is composed of a light orchard bush with a sparse distribution of large trees. The palms may be found growing under this light bush in very considerable numbers, but the main concentrations occur along the banks of streams, along the edges of swamps and particularly on the borders of any artificial clearings. Under Surinam conditions, the species appears to have established itself on the wetter areas, although it cannot be said that it is a swamp denizen as has so frequently been suggested.

Observations on *E. melanococca* in Surinam were confined to the region around Lelydorp and Zanderij. Under these conditions, the palms were all very small and erect, not a single case of procumbency having been seen, although I was assured that they do occur in other parts of the territory. The concentration of these small palms is generally very heavy and on one cleared area there must have been over 100 palms per hectare ; if this density is general throughout the belt in which the species occurs, there must be literally millions of them in the country.

Under these conditions of growth, fruit production is almost nil, but from the few bunches observed it appeared that the fruits were similar in type to those seen in other territories. There is some evidence to suggest, however, that there may be two distinct types; one, a very small fruit containing the usual small kernel, and the other a much larger type with a much larger nut and kernel. Unfortunately, owing to the difficulty of finding fruit bunches which were even approaching maturity it was not possible to pursue this matter further.

The general aspect of these palms also appears to differ from that of *E. melanococca* seen in other parts of South and Central America. Thus, the general aspect of the frond seemed to suggest much more *E. guineensis*, than *E. melanococca*: the fronds were very short, the leaf pinnae were small and slender and particularly they appeared to be more or less alternate rather than opposite, as is the usual case with *E. melanococca*. Furthermore, the pinnae were not inserted on the main rachis on the same plane as is so characteristic of *E. melanococca*, but were more or less identical with those of *E. guineensis*. An additional point concerned the general appearance of the fruit bunch which, with its much more open structure, and less persistent and less sturdy and fibrous spathe, again recall strongly to mind the bunch in *E. guineensis*. There may thus be a question as to the true identity of this palm species, hitherto assigned to *E. melanococca*.

These several considerations indicate the need for a thorough investigation of *E. melanococca* by a competent taxonomist.

Conclusions

1. *E. melanococca* (or *Corozo oleifera*) is widely distributed in Brazil, Canal Zone, Republic of Panama, Costa Rica, Colombia, Surinam.

2. *E. guineensis* has been introduced into E. Brazil (Bahia) from W. Africa. *E. guineensis* and *E. melanococca*, however, were never seen in association in the wild. *E. melanococca* has apparently retained its specific identity without hybridisation with *E. guineensis*.

3. The main interest of the *E. melanococca* lies in its possession of a short trunk. The production and quality of its fruit under natural conditions are disappointing features. (Only one fazenda in Brazil carried palms with fruit that could be considered of any economic interest).

4. A majority of the specimens of *E. melanococca* observed in the several regions had the typical procumbent trunk. Some, however, had not. In different instances, either genetical or environmental factors, or both, may be involved in determining this feature.

5. Despite the poor fruiting qualities of *E. melanococca*, the short trunk character is of sufficient interest to warrant crossings between known high yielding strains of *E. guineensis* and *E. melanococca* being made with a view of incorporating this trunk character into the high yielding strain. It should perhaps be emphasised that it is the short trunk character and not the procumbency, which is desirable. Procumbency, in fact, would create considerable difficulties under plantation conditions.

6. *E. melanococca* is apparently free from many of the diseases to which *E. guineensis* is subject. In the course of this quite extensive reconnaissance, not one single case of known disease was observed. The possibility of increasing resistance to disease in plantation palms by hybridisation, using *E. melanococca* as one of the parents, is a matter of great practical importance.

7. Notwithstanding its long term character, a comprehensive breeding programme, using *E. melanococca* and selected strains of *E. guineensis* as parents, would appear to be justified by the findings of this reconnaissance.

8. This survey has also indicated the interest of and need for a full ecological-taxonomic study of *E. melanococca*.

Acknowledgments

Grateful thanks are expressed to the Board of Directors of the United Africa Company Limited for having made possible this visit to South and Central America and for permission to publish this paper.

In the course of my visit, I received most valuable help and assistance from everyone with whom I came in contact. They are too numerous to mention all individually, but I would single out particularly, Dr. F. Camargo and Dr. R. de L. Froes of Belem, Señor Manuel Vieira of Irmaos Lever S.A., who accompanied me throughout my visit to the Amazon, Dr. Ernest P. Imle of the U.S.D.A. and Paul Allen, Esq., of the United Fruit Company in Costa Rica ; Señor Vargas of the Curacao Trading Company in Colombia and Drs. Ostendorp and Geiskjes of the Landbouwproefstation, Paramaribo, in Surinam.

My thanks are also due to Professor C. W. Wardlaw for much helpful advice and good counsel before the survey and for his helpful criticism in the preparation of this paper.

(*Received for publication, September,* 1951)

THE VIGOUR OF SOME CACAO HYBRIDS

By

T. A. RUSSELL

(*Department of Agriculture, Nigeria*)

Since heterosis has been shown in so wide a range of plants it is surprising to find how scanty are the references to hybrid vigour in writings on cacao. Shephard (5), referring to recent work by students at the Imperial College of Tropical Agriculture, has reported that progenies arising from selfings of two parents were found less vigorous than those arising from crosses.

Voelcker (7) sought hybrid vigour in vain in crosses between seedling trees growing in a plot at Ibadan, Nigeria. He found no significant difference in the vigour of early vegetative growth of crossed and selfed progenies of these trees and he concluded that the parents were too nearly related for vigour to be shown by their hybrids. He suggested that different results might be obtained if crosses were made between parent trees showing a greater degree of variation.

In this paper are described the results of crossing one of the trees used by him with trees of widely different character and the very marked vigour which was in fact exhibited by the hybrid progeny.

The Nigerian Cacao Population

A notable character of Nigerian cacao is the uniformity of much of the crop. Throughout most of the cacao area of the Western Provinces the trees bear the smooth, yellow, and rather blunt pods typical of the cacao known as Amelonado and referred by Cheesman (1) to the group of Amazonian Forasteros. Such uniformity reflects the history of the crop in this country and in particular the rapid development of a large production from a small beginning, the chance introduction of a few pods of this kind.

In scattered areas of Nigeria, particularly some with ready access to the coast, the appearance of red colour and other characters of the fruit suggests that there have been additional introductions of the mixed cacao classed by Cheesman (1) as Trinitario and regarded by him as a mixture of Criollo and Forastero stocks. The effect of these on the main development of the cacao industry has however been small.

Work by botanists of the Department of Agriculture on the improvement of cacao has included selection within the local Amelonado and also within a small sample of Trinitario grown at Moor Plantation, Ibadan since 1912. The selection within this plot, described by Voelcker (6) in 1936, has led to the use of a tree known as T38, chosen for good yield and large bean size, which is now being propagated extensively to provide seed for farmers to plant. Although it approaches Amelonado in many of its vegetative and fruiting

characters, T38 differs in the appearance of a reddish flush on the ridges of the young fruit and greater roughness of the pod and it probably falls within Cheesman's definition of a Trinitario cacao. In Voelcker's opinion (7) it is a first cross between Amelonado and a Trinitario tree.

Introductions From Trinidad

While selection amongst Nigerian cacao was proceeding, it was realised that, for a wider range of characters, introductions of other cacaos would need to be made. O. J. Voelcker visiting Trinidad in 1936 took the opportunity to send planting material from a few trees regarded there as outstanding. The first material to come was in the form of open-pollinated pods picked from two trees growing at River Estate, Trinidad, trees which later became better known as I.C.S.1 and 4 of the Imperial College collection. The pods were sent to the Royal Botanic Gardens, Kew, the seedlings were started there and were then forwarded to the Department of Agriculture, Nigeria, after a suitable period of quarantine.

The female parents of these seedlings, I.C.S.1 and I.C.S.4, have been described by Pound (3). Both are of Trinitario type, I.C.S.1 being a self-compatible tree with red pods of a long pointed shape, with a constriction at the neck and deeply corrugated shell. I.C.S.4 on the other hand is described as self-incompatible with pods of a waxy or whitish green, large, broad, and deeply furrowed and corrugated. The male parents of the open-pollinated seedlings with which we are concerned are unfortunately not known.

The trees into which these seedlings developed varied amongst themselves and differed in some respects from their female parents. Thus of five seedlings of I.C.S.1 (a self-compatible tree) four were proved to be compatible while one gave evidence of self-incompatibility. Of ten seedlings of the self-incompatible I.C.S.4, four proved compatible while six were thought to be self-incompatible. In pod-colour also there was much diversity, some of the seedlings from the red-podded I.C.S.1 showing little or no red coloration whereas one or two of the progeny of the unpigmented I.C.S.4 developed red coloration on a whitish base. The seedlings descended from I.C.S.1 tended to be low-branching and bushy in habit whereas those of I.C.S.4 parentage showed a tall straggling growth.

Three of the self-compatible and green-podded seedling-trees (two derived from I.C.S.1 numbered CF59 and CF62, and one from I.C.S.4 numbered CF176) were selected for further work. It was decided in particular to find how the progeny of these trees of Trinidadian origin compared in yield with progeny of the Nigerian selection and with the progeny of a marriage of the two races. Accordingly, in the year 1941, flowers of the Nigerian T38 were fertilised with pollen from the three Trinidad seedlings using the technique described by Pound (4). The pods thus set produced the seed of the Nigerian-Trinidad hybrids used in the planting experiment. Selfed seedlings of the Nigerian selection and of the Trinidad plants were produced similarly by controlled pollinations.

The Progeny Trial

In a field-trial the following nine groups of seedlings were used:—

	Groups	
Trinidad type ...	A:	selfed-seedlings of tree CF176, an open-pollinated seedling of I.C.S.4.
	B:	selfed seedlings of tree CF59, an open-pollinated seedling of I.C.S.1.
	C:	selfed seedlings of tree CF62, an open-pollinated seedling of I.C.S.1.
Nigerian type	D:	selfed seedlings of T38.
	E:	selfed seedlings of tree CD176, a selfed seedling of T38.
	F:	selfed seedlings of tree CD207, a selfed seedling of T38.
Nigerian × Trinidad Crosses	G:	seedlings from cross T38 × CF176
	H:	seedlings from cross T38 × CF59
	J:	seedlings from cross T38 × CF62

The nine lots of seed were sown in nursery in 1941 and the seedlings were planted during the following rainy season at Ina Cacao Farm 13 miles south of Ibadan in plots replicated nine times in the form of a latin square. Each plot contained nine trees planted twelve feet apart. Establishment was good in the first year and little supplying had to be done.

Vegetative Vigour

From the start the hybrids made more vigorous growth than the selfed seedlings. This is expressed quantitatively in measurements of stem-girth at three inches above ground-level which were made in 1948 six years after planting.

Table I. *Mean stem-girth of 9 groups of seedlings*

Group		Mean girth per tree in inches
Trinidadian	A	7.7
	B	8.3
	C	9.2
Nigerian	D	9.2
	E	8.2
	F	9.2
Nigerian x Trinidad	G	10.9
	H	10.3
	J	10.7

A difference of 1.2 ins. is significant at P = 0.01 or a difference of 0.94 in. at P = 0.05.

By 1951, nine years after planting, the plots of hybrids were easily to be recognised by the robustness of the trees, their greater spread and thickness of canopy.

Early Fruitfulness

The greater vegetative growth of the hybrids was accompanied by earlier production of fruit. In the fourth year after planting when fruiting first became general, 275 pods were taken from hybrid trees as against 56 from Trinidadian and 11 from Nigerian seedlings.

The hybrids maintained their superior yield in succeeding years. In the following table are shown the total yields expressed as weight of wet beans per acre obtained over the first five years of fruiting, that is until the end of the eighth year after planting.

Table II. *Weight of wet beans produced by cacao seedlings of different origin in the first five years of fruiting*

Group		Total Wt. wet beans (lbs. per acre)
Trinidadian	A	466
	B	1,237
	C	932
Nigerian	D	790
	E	756
	F	364
Nigerian x Trinidad	G	3,751
	H	2,573
	J	2,675

A difference of 930 in treatment totals is regarded as highly significant ($P = 0.01$)

From these figures it will be seen how much earlier the hybrids have been in production than the parent types.

The yield of the plots of the Nigerian-Trinidadian cross G in its eighth year after planting was equivalent to 1,011 lb. of dried cacao per acre. This greatly exceeds the yields hitherto recorded for cacao of that age in Nigeria. Records of Nigerian Amelonado show that the yield of a tree normally increases up to the age of 20 or even 25 years. It has yet to be seen whether these hybrids will follow a similar course of increasing yields or whether their greater early yield represents a quicker attainment of full production. The yield of the Nigerian parent T38 up to its eighth year is disappointingly small and indicates that it is slow in reaching heavy production.

The hybrids showed a range of pod characters intermediate between those of their parents. In general the fruits were longer and more deeply furrowed and corrugated than the Nigerian T38, but broader and more rounded at the tip than the Trinidadian seedlings.

The hybrids had no clear superiority in size of bean over the parent types, and it is evident that their higher yield came from the greater number of pods and of beans produced rather than from larger beans. Expressed as number of pods required to produce 1 lb. of dried cacao, the mean figure in the season 1950–51 was 10.9 for the hybrids as against 11.1 for both the Nigerian and the Trinidadian seedlings. In calculating these figures it is assumed that 100 lb. of wet cacao yield 42 lb. of dried beans. A few trees of clonal I.C.S.1 gave the lower figure of 8.7 but, as these were grown in another farm under different conditions, it is doubtful if the figures are strictly comparable. All these values are poor when it is borne in mind that Pound (2) looked for 1 lb. of dried cacao from 7.5 pods in his Trinidad selections and that the original tree of I.C.S.1 is described by him (3) as having a pod-value approximating to 6.5. It may well be that, in the more exacting growing conditions of the Ibadan district of Nigeria, pod-value is depressed below the level reached in the more favourable conditions of Trinidad.

Summary

A yield trial is described in which the selfed progeny of a Nigerian cacao of Trinitario type was compared with selfed seedlings of a Trinitario cacao from Trinidad and with hybrids of the two types.

2. The hybrid seedlings showed marked superiority in early vigour of growth and in early production. The greater yield resulted from the larger number of pods produced rather than from greater bean size.

Acknowledgments

This work was started by O. J. Voelcker and continued by successive Botanists of the Nigerian Department of Agriculture, Messrs J. West and G. K. G. Campbell, to whom and to Mr. Quarcoo, the Assistant in charge of Ina Cocoa Farm, acknowledgements are due. I am also grateful to Mr. West, now Director of the West African Cacao Research Institute, for reading this paper and referring me to relevant literature. I am indebted to the Director of Agriculture, Nigeria, for permission to publish this record of work.

LITERATURE CITED

1. Cheesman, E. E. Notes on the Nomenclature, Classification, and possible Relationships of Cacao Populations. *Trop. Agriculture, Trin.* 1944. **21** p.144.
2. Pound, F. J. Criteria and Methods of Selection in Cacao. Second Annual Report on Cacao Research 1932, p.27. *Imp. Coll. Trop. Agr. Trinidad*, 1933.
3. Pound, F. J. The Progress of Selection 1933. Third Annual Report on Cacao Research 1933 p.25. Trinidad 1934.
4. Pound, F. J. A Note on a Method of Controlled Pollination of Cacao. Fourth Annual Report on Cacao Research 1934 p.15. Trinidad 1935.
5. Shephard, C. Y. A Progress Report on Cocoa Research at the Imperial College of Tropical Agriculture. Report of Cocoa Conference, 1951, p.58. The Cocoa, Chocolate & Confectionery Alliance, Ltd., London.
6. Voelcker, O. J. Initial Cacao Selection in Nigeria. Eleventh Bulletin of the Agricultural Department, Nigeria. Government Printer, Lagos 1936, p.45.
7. Voelcker, O. J. Growth rate of cross and self-fertilized Cacao. *Trop. Agriculture, Trin.* 1936. **16.** p.203.

(*Received for publication, January*, 1952)

LITTLE LEAF DISEASE OF THE OIL PALM (*ELAEIS GUINEENSIS*), IN THE BELGIAN CONGO

By

W. G. KOVACHICH

(*Plant Pathologist, Huilever S.A., Leopoldville, Belgian Congo*)

Summary

The external and internal symptoms of this disease are described and information is given concerning the distribution and spread of the disease.

The investigation has shown that Bud Rot and Little Leaf are two stages of the same disease of the oil palm which is now referred to as Little Leaf disease. No insect, fungus or bacterium has been found in constant association with the disease, and tissues displaying very early symptoms were free from infection by any micro-organism.

The Bud Rot condition has been reproduced in healthy palms, by damaging the roots.

Evidence is forwarded which suggests that the susceptibility of palms to Little Leaf is influenced by fruit production and soil conditions.

It is concluded that the disease is not primarily caused by insects or micro-organisms but that it is either of physiological or virus origin.

Introduction

The most serious disease of young oil palms in the southern region of the Belgian Congo, at the present time, is the Bud Rot/Little Leaf complex. Bud Rot and Little Leaf have, in the past, been considered as two separate diseases. Ghesquiere (1935) reported that *Phytophthora palmivora* was the causal organism for the Bud Rot condition whilst others have suggested that Bud Rot results from insect injury. *Thielaviopsis basicola* has been cited as the pathogen for the Little Leaf condition (INEAC 1948).

Detailed investigations have shown that the first leaves to open after recovery from Bud Rot are of the Little Leaf type, which suggests that Little Leaf is a recovery condition of Bud Rot. The malformation of the Little Leaf leaves, however, occurs prior to the rotting of the young leaves and affects the leaves before they open. Thus the Bud Rot and Little Leaf conditions are different stages of the same disease. As Little Leaf is the first abnormality to occur and as the disease is not always associated with a rotting of the young leaves, it is considered more correct to refer to this disease as Little Leaf disease in preference to Bud Rot.

Little Leaf of the oil palm is extremely similar to the *Phytophthora* Bud Rot of the coconut palm.

Incidence and Spread

No information is available concerning the distribution of the disease in countries other than the Belgian Congo. In the Belgian Congo, Little Leaf has been observed in all the plantations visited, but whereas relatively few palms are affected in the northern region, Little Leaf accounts for 20 per cent. to 25 per cent. of the young palms in parts of the southern region plantations.

Two year old palms have been observed with the disease. Normally, however, oil palms are most susceptible to Little Leaf between six and twelve years after transplanting, with the greatest losses occurring between seven and ten years. Palms older than twelve years are more rarely attacked and usually make a more rapid recovery than do younger palms.

The spread of the disease is usually from a palm affected by Little Leaf to either an adjacent palm or the next palm but one. New cases of the disease occur extremely rapidly as do changes from the Bud Rot condition to the Little Leaf condition. It is common to find a palm displaying early symptoms of Little Leaf adjacent to a palm which is beginning to recover from the disease. Table I shows the changes which took place in a group of 1,538 palms which were kept under observation for a period of six months.

Table I. *Changes in the Little Leaf Situation in a Group of* 1,538 *Palms during a Period of Six Months*

Period	Healthy to Bud Rot	Bud Rot unchanged	Bud Rot to Dead	Bud Rot to Little Leaf	Little Leaf to Bud Rot
April-June ...	23	45	13	27	25
June-August ...	7	71	8	14	22
August-September	10	82	5	13	7
September-October	28	83	1	15	14

The damage done to the oil palm as a result of the disease varies greatly. Little Leaf may be fatal, prevent growth of the palm for several years, or it may only cause slight damage to a single whorl of leaves. Some palms completely recover from the disease whilst others, after an apparent recovery, undergo a second or even a third attack of the disease.

External Symptoms

The earliest external symptom of Little Leaf is the abnormal habit of the innermost whorl of opened leaves. These leaves are considerably shorter and more erect than the corresponding leaves of a healthy palm. They are usually healthy in appearance but may be slightly chlorosed. When the palm first exhibits this symptom, the young, unopened leaves of the central spear are free from any rotting. Later, a dark brown rotting of the unopened pinnae may be observed and this is followed by the collapse of the central spear at a point within the central frond cylinder. The central spear can then be

withdrawn from the central frond cylinder and it is found that the young leaves are completely rotted at the point of collapse. The rotted tissues are greyish-white in colour and of the consistency of a wet putty. A characteristic putrid smell is associated with the rot. With age the rotted tissues become orange and then brown coloured and become infested with insect larvae.

The progress of the disease depends on the severity of the attack. The trunk apical meristem may be destroyed (Plate 1) and result in the death of the palm, or the rot may be arrested before reaching the meristem, by the formation of callus tissue in the leaf rachids. In the latter case, growth of the young leaves may be resumed almost immediately or growth may be arrested for several years. It is not uncommon to find that even when the growth of the leaves is completely arrested, fruit bunches continue to develop.

The first leaves to open after the rotting of the central spear are of the Little Leaf type, i.e. they are considerably smaller than normal and are also distorted.

The distortion of the first leaves to open may be of a mechanical type due to the necrosis of some of the pinnae and the rachids as a result of the leaves being involved in the rot. Subsequent leaves are usually untouched by the rot but are extremely small and malformed (Plate 2). The malformation normally consists of the pinnae being corrugated or completely lacking. Occasionally, the leaf rachids are also distorted. Succeeding leaves are usually less malformed and approximate more to healthy leaves until the palm is indistinguishable from a healthy palm. Palms which have apparently recovered from Little Leaf frequently suffer a second or third attack of the disease and these later attacks are commonly of a more serious nature.

Little Leaf type of leaves occasionally appear on palms without the central spears being previously rotted.

Some palms, on recovery from a serious rot, produce two or more central spears so that branching of the trunk results, if the recovery is maintained.

Internal Symptoms

1. *The Bud and Central Spear*

Palms displaying the earliest external symptom of the disease frequently possess some abnormality of the bud or central spear. The extent of this abnormality is extremely variable. Thus, with extreme cases, the young leaves and leaf primordia are much compressed and abnormally white when compared to the cream to yellow colour of a healthy bud. The distribution of this abnormal tissue is such as to suggest that all the affected leaves were affected at the same time. Similar abnormal tissue is occasionally found in the trunk of the palm immediately below the apical meristem (Plate 3).

Some palms displaying early symptoms of Little Leaf possess apparently healthy buds but the very young leaves of the central spear, i.e. those with visible pinnae, are distorted (Plate 4). Some of these leaves have both the pinnae and the rachids malformed whilst others have corrugated leaflets or some of the pinnae completely missing. Many of these leaves show signs of callus formation close to the surface of the rachids although there is no rotting of the young leaves. These distorted young leaves are identical, excepting for age, with the Little Leaf leaves and are, in fact, the first leaves to open when growth is resumed after the rot has been arrested.

The rotting of the young leaves occurs after the malformation of the leaves in the bud region and first affects the young leaves at a point 30–40 cms. above the bud, i.e. older leaves than the distorted leaves. Insects are absent from recently rotted tissues and all the rotted tissues appear homogeneous and in a similar state of decay. There is a sharp line of demarcation between the healthy and rotted tissues and a well developed callus layer is normally present.

Mature leaves of the Little Leaf type have the tissues of the rachids slightly orange coloured and there is commonly a well developed callus layer immediately below the surface of the rachids.

2. *The Trunk*

In practically all palms affected with a recent rot of the central spear or bud, the trunk is apparently healthy. With severe, long standing attacks of the disease, a dull red coloration of the ground tissue and, occasionally, the vascular strands may be observed in the crown region of the trunk. The discoloration is most intense in the immediate vicinity of the rot when the rot has entered the trunk. The red colour persists after the palm has recovered from the disease.

The Roots

Healthy root tips are absent from the root systems of palms displaying early symptoms of Little Leaf. The majority of the roots are of the arrested type with the tips covered by a hard exodermis. These roots have been previously described (Kovachich 1952).

The growth of the arrested roots may be resumed shortly after the appearance of the rot in the central spear, but normally, healthy root tips are not produced until a considerable time after the opening of leaves of the Little Leaf type.

PLATE I—L.S. Bud region of recently rotted palm.

PLATE 2—Mature Little Leaf type leaves (Ruler = 50 cms.).

PLATE 3—L. S. (not median) bud of Little Leaf palm with abnormal tissue at the tips of the leaves and below the trunk apical meristem.

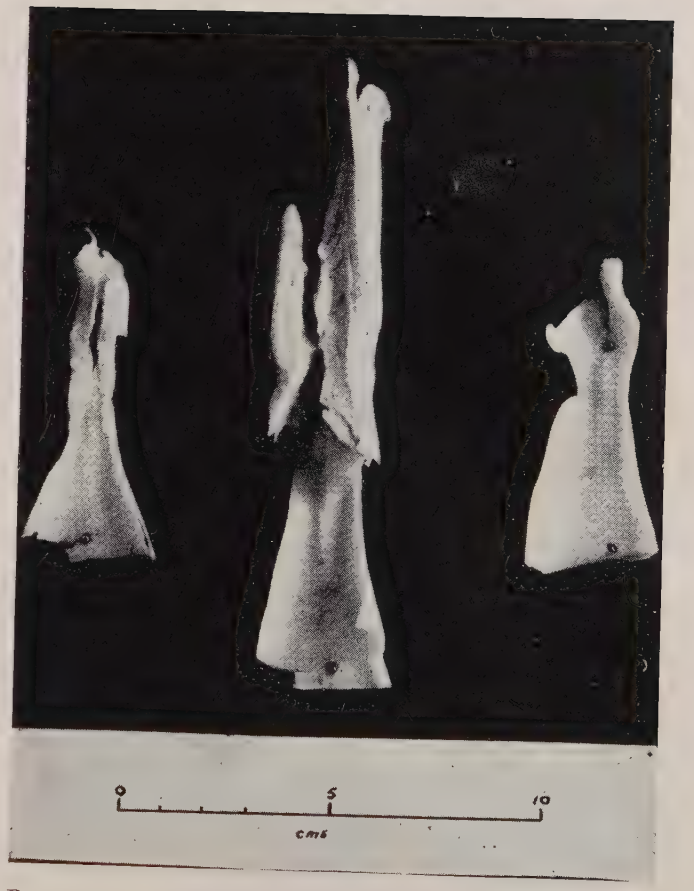


PLATE 4—Very young leaves of the Little Leaf type.

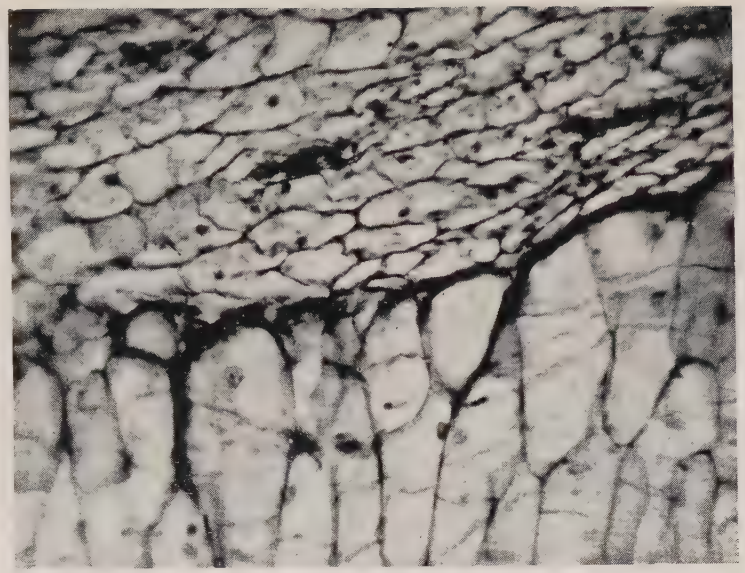


PLATE 5—L.S. part of bud of Little Leaf palm. Healthy tissue below, abnormal tissue above.

PLATE 6—Rotted young leaves produced as a result of cutting the roots.

1. *Microscopical and Cultural Observations*

Cultures of abnormal tissue from affected buds and parts of young malformed leaves all failed to yield bacteria or fungi. Cultures of recently rotted leaves resulted in the isolation of numerous bacteria and occasional fungi, but no single bacterium or fungus was isolated with sufficient constancy to suggest pathogenic complicity.

No isolates were obtained from cultures of the dull red coloured tissue of the crown region of the trunk or from the arrested roots. No specific micro-organism was consistently isolated from rotted roots of bud-rotted palms.

The examination of microscopical preparations of the various diseased tissues supported the cultural evidence in that no micro-organisms were seen in association with arrested roots, abnormal bud tissue, or with the red coloured tissues of the trunk.

The cells of the abnormal tissues in the buds were considerably smaller than the cells of adjacent healthy tissue and these cells contained abnormal nuclei. The nuclei of the abnormal cells were irregular in shape and smaller than the corresponding normal nuclei (Plate 5).

All of the sections of abnormal buds examined showed the presence of a cambial layer between abnormal and healthy tissues.

2. *Inoculation Experiments*

The more common isolates obtained from cultures of recently rotted leaves, six bacterial and four fungal, were incubated on Richard's fluid and then poured over the young unopened leaves of healthy palms. Eight palms were inoculated with each isolate and the young leaves of four of these palms were first damaged by thrusting a serrated rod into the central spear. All of the treated palms remained free from Little Leaf.

The experiment was then repeated using recently rotted leaves from a Little Leaf palm as the inoculum. The treated palms failed to show symptoms of Little Leaf.

3. *Surgical Treatment of Affected Palms*

Seventy palms with a rot of the young leaves were selected. These palms were then subdivided into fourteen sub-plots of five palms each and one palm of each sub-plot was subjected to one of the following five treatments:

1. Left as control
2. Old leaves removed to expose the rotted tissues
3. The same as 2. except all the rotted tissues were cut out
4. The same as 3. except the cut surfaces were treated with D.D.T.
5. The same as 4. except that Perenox fungicide was also dusted on the cut surfaces.

The treated palms were kept under observation for a period of seven months after which period the following number of recoveries had taken place.

Treatment 1. (14 palms) Control	6 recoveries
Treatment 2. (14 palms) Rot exposed	3 recoveries
Treatment 3. (14 palms) Rot removed	5 recoveries
Treatment 4. (14 palms) Rot removed + D.D.T.	5 recoveries
Treatment 5. (14 palms) Rot removed + D.D.T. + Perenox	4 recoveries

4. *To Test if Bud Rot can Result from Damaging the Roots*

Seven healthy, young palms (5–6 years) were selected for this experiment. The roots of these palms were then cut at a point 50 cms. from the base of the trunk and the soil was replaced around the palm. All of the palms were uprooted and examined four months later.

Four of the seven palms displayed an active rot of the young leaves of the central spear. The rot was identical to that associated with Little Leaf (Plate 6). The young leaves of one of these palms also possessed abnormal shrunken tips and some of the pinnae were corrugated.

Cultures of the rotted tissues resulted in the isolation of bacteria and fungi commonly associated with the bud rot condition of Little Leaf.

5. *Susceptibility to Little Leaf*

As observations had shown that many palms suffer an attack of Little Leaf after a heavy fruit yield, attempts were made to determine if any correlation existed between fruiting and susceptibility.

A fruit survey was carried out on 100 palms which had developed a recent rot of the central spear and 200 healthy palms selected at random.

It was found that the average number of healthy fruit bunches per palm for the Little Leaf palms was 2.81 whilst the healthy palms averaged 2.28 fruit bunches per palm.

Whereas only 10 per cent. of the healthy palms possessed aborted fruit, the fruit was aborted on 21 per cent. of the Little Leaf palms. No fruit bunches were found on 26.5 per cent. of the healthy palms and 21 per cent. of the Little Leaf palms.

The fruit production of palms is correlated with the type of palm, thus the *tenera* type produces more fruit bunches than the *dura* type, whilst the *pisifera* type produces more female flowers than either of the other two types although they rarely reach maturity.

In a selected block, the ratio between *dura, tenera,* and *pisifera* healthy palms was 48: 35: 17 respectively, but the ratio between the three types of Little Leaf palms was 22: 55: 23. Thus the *dura* type of palm appears to possess more resistance to the disease than do the *tenera* and *pisifera* palms.

Discussion

The results of the present investigation leave little doubt as to the complexity of the disease. Apart from the active rotting of the young leaves, associated abnormal conditions have been reported in the bud, the trunk and the roots.

It has been shown that the rotting of the young leaves is the final stage of the disease and the only stage associated with micro-organisms. Thus, before the rotting, the roots become arrested, the youngest open leaves fail to expand fully, abnormal tissue is formed in the bud meristematic regions, callus formation commences and the young leaves become distorted. It is, therefore, apparent that the micro-organisms associated with the rot cannot be responsible for the disease. This view is supported by the failure to transmit the disease by inoculation with these micro-organisms and by the failure to cure the disease by cutting out the rotted tissues. As insects are absent from the abnormal tissue, distorted leaves and very recently rotted leaves, Little Leaf is not caused primarily by insects.

The abnormal condition of the roots has previously been shown to be of a physiological nature and has been reproduced in healthy palms by removing the pinnae from the opened leaves. Similar abnormal root systems are also associated with some palms with the disease known as Plant Failure, although the buds of these palms are healthy. Little Leaf palms frequently recover from the disease without any improvement in the condition of the roots. Therefore the condition of the roots cannot be the cause of the disease.

As insects or micro-organisms are not the cause of the disease, Little Leaf must be considered as being of physiological or virus origin.

The spread of the disease is highly suggestive of Little Leaf being a virus disease. The presence of abnormal tissue in the meristematic regions of the bud and the distortion of the young leaves are also in keeping with this view. The course the disease takes, however, is unlike any known plant virus disease in that palms do recover from the disease and after recovery are susceptible to further attacks of the disease.

The distribution of the disease is suggestive of soil factors and/or rainfall influencing the palms' susceptibility to the disease. Thus, in the southern region of the Belgian Congo, where the disease is most severe, the soil is impoverished and there is a dry season of two and a half months duration.

The susceptibility of high fruit yielding palms to Little Leaf is also in favour of the cause of the disease being physiological. It is also interesting to note that with the raffia palm (*Raphia Vinifera*), which is systematically akin to the oil palms, but which dies after fruiting, the last leaves to appear before the fruit are considerably shorter than normal. All the roots of fruit-bearing raffia palms are of the arrested type.

The appearance of the cells of the abnormal tissue suggests that the cells have failed to expand after their formation and this is supported by the fact that abnormal tissue readily takes up water with subsequent expansion. Thus it may be argued that the abnormal tissue is caused by the failure of the cells to take up water rather than that it is produced by the abnormal proliferation of cells associated with some virus diseases.

Further support for the ' physiological ' theory is that both the rotting of the young leaves and the arrested condition of the roots have been reproduced by interfering with the palm's physiology, i.e. by cutting the roots or removing the pinnae.

It has not, however, been possible to correlate the appearance of the disease with any single environmental condition.

ACKNOWLEDGEMENTS

The writer wishes to thank Huilever S. A. for permission to publish this report and Professor C. W. Wardlaw for help in the preparation of the report.

REFERENCES

GHESQUIERE, J. 1935 "Rapport preliminaire sur l'état sanitaire de quelques palmeries de la province de Coq." INEAC Sci. 3.

INEAC 1948 "Rapport Annuel pour l'Exercice 1947."

KOVACHICH, W. G. 1952. "Abnormal Roots in Oil Palms in the Belgian Congo.', *Tropical Agriculture*, XXIX, 29.

(*Received for publication, March,* 1952.)

EVALUATION OF SOME TROPICAL GRASS-LEGUME ASSOCIATIONS[1]

By

H. E. WARMKE, R. H. FREYRE, AND J. GARCIA

(*Federal Experiment Station in Puerto Rico, Office of Experiment Stations, U.S. Department of Agriculture, Mayaguez, P.R.*)

Summary

Combinations of five legume species with Merker grass (in addition to Merker grass and tropical kudzu alone) were grown in a replicated field experiment at the Federal Experiment Station in Puerto Rico. Three of the legumes, cowpea, velvetbean, and red bean, could not be established or maintained successfully in association with Merker grass. Two other species, tropical kudzu and trailing indigo, grew successfully in association with Merker grass through repeated cuttings over a period of 3 years. The compatible combinations significantly outyielded either grass or legume grown separately in total forage and in total protein. They also yielded more of the four minerals, calcium, magnesium, phosphorus, and potassium. The increased yields of the compatible combinations are not considered to result from a beneficial effect on either component as a consequence of the association, but rather from a tendency for summation of individual yields of the components grown separately. This is attributed to a more efficient use of available soil, sunlight, and moisture by the associations.

Introduction

Grass-legume associations are utilized widely for forage in the Temperate Zone. The utilization of such associations in the Tropics, however, is much less common and in most areas is rare. This is due partly to the scarcity of good tropical legume species and partly to a lack of information on suitable combinations and to a general lack of understanding of forage practices. The studies of Paterson (4, 5), of Loustalot and Cernuda (2), and of Rivera Brenes (6) have made important initial contributions. The purpose of the present study was to try various grass-legume combinations and to determine the yields, protein, and mineral content of these combinations as compared with the grass and legumes grown separately.

Materials and Methods

Five different legume species, (1) tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.), (2) trailing indigo (*Indigofera endecaphylla* Jacq.), (3) velvetbean (*Stizolobium Deeringianum* Bort), (4) red bean (*Canavalia bonarensis* Lindley), and (5) cowpea (*Vigna sinensis* (L.) Endl.) were grown in combination with Merker grass (*Pennisetum purpureum* Schum. var. Merkerii). Plots of Merker grass alone and tropical kudzu alone were planted as checks.

---

[1]Contribution from the Federal Experiment Station in Puerto Rico in co-operation with the Experiment Station of the University of Puerto Rico, the USDA Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Soil Conservation Service.

A randomized block design was used, with four replications and plots of 1/100 acre in size. The planting was made on a fertile, alluvial Toa silty clay loam. As is characteristic of experiments with perennial crops, the randomization was not changed from year to year. Accordingly, the error *a*) and error (*b*) type analysis of variance was used in statistical treatment of the data. Seeds of the legumes were planted in rows 3 feet apart, and seed pieces of Merker grass were planted 3 feet by 2 feet between the rows of legumes. Annual legume species were replanted as necessary. No fertilizer was added during the course of the experiments.

The trials were started in November, 1947 and were continued for 3 years. The Merker grass was cut when it was in prime condition for cutting and not at specific time intervals. The times between cuttings varied from 9 weeks to 5 months, depending largely on rainfall during the period. In all a total of 10 harvests were made. If a legume had made sufficient growth at the time the grass was harvested it also was harvested; if not, no harvest of the legume was made. When a harvest did not coincide with the end of a year, the weight of forage for the harvest in question was divided in proportional parts in calculating a year's production.

Harvesting was done by hand, the grass being cut by machete near the surface of the ground and the legumes at heights of 4 inches (trailing indigo) to 8 inches (kudzu), with a sickle. In all combinations, the grass and legume were separated at harvest and the weights of each recorded. Samples for dry weight determinations and for chemical analyses were taken from 5 different areas (separately for grass and legume, in combinations) from each plot for each replication for each harvest. The samples from each replication of checks and compatible combinations were analyzed for nitrogen, but for mineral analyses samples from the four replications were thoroughly mixed and one analysis made of the compounded sample for each species for each harvest.

Results

The first harvest of grass was made after 7 months. Of the legumes, only red bean and velvetbean had made sufficient growth to be cut at this time. Tropical kudzu and red bean had made sufficient growth to be cut at the second harvest, but none of the other legumes.

After a few harvests, it became evident that some of the legumes could not grow satisfactorily in combination with Merker grass. The cowpeas, for example, never made sufficient growth to be harvested. Velvetbeans in combination with the grass were harvested only once, and the red bean plots were harvested only five times. Combinations of these three legumes with Merker grass may be considered incompatible on a long-term basis and of little value. Although constantly replanted, these legumes could not be maintained in successful combination with the grass. The exact reason for this is not known, but it is suggested it may be due to the severe root competition and shading afforded by the Merker grass. It is of interest that all three of these legumes are annual or biennial and perhaps could not compete with the perennial grass.

The remaining two combinations—Merker grass and tropical kudzu and Merker grass and trailing indigo—may be considered as compatible combinations under the conditions of the experiment. These two perennial species grew vigorously with the grass and recovered well after cutting. The kudzu vines twined up the stout Merker grass stems (Fig. 1) and the trailing indigo made a thick, dense mat over the surface of the soil (Fig. 2).

Total forage yields (dry weight) are given in Table I. The combinations are listed in order of yield, beginning with Merker grass-trailing indigo, which produced an average of 24,526 pounds per acre per year and ending with kudzu alone, which produced an average of 6,620 pounds per acre per year. Statistical analysis of the data shows the value of " F " for combinations, for years, and for the interaction years × combinations to be highly significant. The least significant difference between the means of the combined totals is 4,198 lb./acre/yr. This indicates that the Merker grass-trailing indigo and Merker grass-kudzu combinations are not significantly different in yield, but that both are significantly better than the Merker grass-cowpea combination and all those below it. Tropical kudzu alone was definitely poorest. The two compatible combinations thus significantly outyielded either the Merker grass grown alone or the kudzu grown alone. Actually, the yield of each of these combinations was approximately equal to the yield of the Merker grass alone plus the kudzu alone (17,104 + 6,620 = 23,724 lbs/acre/yr).

TABLE I. *Forage yields (oven-dry weight) of grass-legume associations, Mayaguez, P.R., 1948–50*

Combinations	1948[1]	1949[1]	1950[1]	Mean 1948–50 (Dry matter)	
	lb./plot	lb./plot	lb./plot	%	lb./acre/yr.
Merker grass +	153.8	180.7	206.9	20.7	18,046
Trailing indigo	—	92.1	102.3	23.6	6,480
Combined total	153.8	272.8	309.2		24,526
Merker grass +	136.6	157.7	160.1	20.3	15,147
Tropical kudzu	38.7	105.3	77.0	22.2	7,366
Combined total	175.3	263.0	237.1		22,513
Merker grass +	146.6	166.2	168.1	20.5	16,029
Red bean	104.1	17.7	10.3	24.6	4,404
Combined total	250.7	183.9	178.4		20,433
Merker grass +	176.3	173.7	171.6	20.6	17,385
Cowpea	—	—	—	—	—
Combined total	176.3	173.7	171.6		17,385
Merker grass alone	147.1	179.2	186.8	20.5	17,104
Merker grass +	154.4	170.6	154.4	20.1	15,980
Velvetbean	23.4	—	—	24.1	780
Combined total	177.8	170.6	154.4		16,760
Tropical kudzu alone	51.3	87.4	59.9	19.1	6,620
L.S.D. for combined totals at 5 per cent. level					4,198

[1]Mean yield of 4 replications (plots 1/100 acre each in size).

The high yield of the Merker grass-trailing indigo combination is notable, in view of its late start. The legume was not planted in these plots until more than 8 months after the start of the experiment * and, consequently, was not ready for harvest until the second year. The significant "F" values for years and for years × combinations are apparently due to the fact that the yields were generally low the first year—when the forages were being established—and to a different response of individual legumes to different years. For example, red bean produced well only during the first year; whereas trailing indigo had its highest production the last year.

Table II gives nitrogen and protein yields of the forage from the experimental plots. Nitrogen values were obtained by multiplying dry weights for each plot by per cent. nitrogen in the samples from that plot, and protein values were obtained by multiplying nitrogen by the factor 6.25. The least significant difference for mean total protein yield was found to be 238 lb./acre/yr. This indicates that Merker grass alone was significantly poorest in protein yield, that kudzu alone was better, but that the two grass-legume combinations were significantly superior in protein yield to either grass or legume grown separately. Again it should be noted that the total protein yield of the grass-legume combinations is approximately equal to the yield of the two components grown separately. It is also of interest that the Merker grass grown in combination with either trailing indigo or kudzu did not produce more protein (621 and 615 lb./acre/yr.) than the grass grown alone (628 lb./acre/yr.). The legumes contained between 15.5 and 17.2 per cent. protein (oven-dry basis) or about four times the protein content of the Merker grass (3.4 to 4.1 per cent.).

TABLE II. *Nitrogen and protein production for grass-legume associations for the years 1948–50, Mayaguez, P.R.*

Combination	Nitrogen 1948[1]	Nitrogen 1949[1]	Nitrogen 1950[1]	Mean 1948–50		
				Nitrogen	Protein (N. x 6.25)	Protein (N. x 6.25)
	lb./plot	lb./plot	lb./plot	lb./plot/yr.	%[2]	lb./acre/yr.
Merker grass+ ...	1.031	1.068	0.880	0.993	4.1	621
Kudzu	0.797	2.806	1.877	1.827	15.5	1,142
Combined total	1.828	3.874	2.757	2.820		1,763
Merker grass + ...	0.834	0.953	1.166	.984	3.4	615
Trailing indigo ...	—	2.298	2.705	1.668	16.1	1,043
Combined total	0.834	3.251	3.871	2.652		1,658
Kudzu alone ...	1.157	2.639	1.677	1.824	17.2	1,140
Merker grass alone ...	1.025	1.008	0.982	1.005	3.7	628
L.S.D. for combined totals at 5% level						238

1 Mean yield of four replications (plots 1/100 acre each in size).
2 Weighted averages of all analyses.

*These plots were originally planted to another legume. Trailing indigo cuttings were started on July 28, 1948, after the seed of the first legume failed to germinate.

FIG. 1—Two-year-old association of Merker grass and tropical kudzu. Note the legume vines climbing on the Merker grass stalks higher than a mans' head.

FIG. 2—Merker grass-trailing indigo also constitutes a compatible association. The legume forms a dense mat, 2 to 2½ feet in thickness at the base of the grass.

Table III gives mineral composition of the forage from the experimental plots. In general, the legumes are notably higher in the percentage of calcium and magnesium than the Merker grass and somewhat lower in the percentage of phosphorus and potassium. This is true whether the grass and legumes are grown separately or together. These data also indicate that the combination plots yield more of these four minerals, in pounds per acre per year, than the plots with only the grass or only the legume.

TABLE III. *Mineral composition of forage (oven-dry basis) from grass-legume associations Mayaguez, P.R., 1948–50*[1]

Combination	Calcium[2]		Magnesium[2]		Phosphorus[2]		Potassium[2]	
	%	lb./acre/yr.	%	lb./acre/yr.	%	lb./acre/yr.	%	lb./acre/yr.
Merker grass + ...	0.23	41	0.29	52	0.40	73	1.66	300
Trailing indigo ...	1.79	116	.47	31	.30	20	.84	54
Combined total		157		83		93		354
Merker grass + ...	.26	39	.26	40	.39	59	1.53	233
Kudzu	.95	70	.54	40	.26	19	.72	53
Combined total		109		80		78		286
Kudzu alone ...	.88	59	.44	29	.33	22	1.16	77
Merker grass alone...	.24	41	.22	37	.39	66	1.66	284

[1]Based on means of analyses of one compounded sample from the four replicates for each of 10 harvests during the years 1948, 1949, and 1950.

[2]Reported as pure Ca, Mg, P, and K.

Discussion and Conclusions

The results of these trials show certain limitations as well as definite advantages of tropical grass-legume associations. It is clear that the matter of grass and legume being able to live together under given conditions of growth and methods of harvesting *—and of being able to maintain themselves—is very important. Three of the five original legume species used in these tests were found to be incompatible with Merker grass. This information probably cannot be arrived at empirically, but must be obtained from actual field tests.

The two combinations found to be compatible in these trials (Merker grass-tropical kudzu and Merker grass-trailing indigo) outyielded either the grass or legume grown separately in total dry matter, in protein, and in the four minerals, calcium, magnesium, phosphorus, and potassium. The grass and legume in combination produced about as much on one acre as the two components, grown separately, did on two acres.

* Recent tests at this station showed that a well-established association of *Panicum purpurascens* and tropical kudzu was compatible when grazed, but incompatible when cut. The preference of the cattle for the grass during grazing provided a slight selective advantage to the legume, but equal treatment when cut (even at three different heights) proved too severe for the legume in the combination.

The increased production of protein by the associations is of special importance in the Tropics. Under the conditions of this experiment the kudzu-Merker combination yielded over 2½ times more protein than the grass alone. In Puerto Rico hundreds of acres of Merker grass are being grown under similar conditions on lands capable of producing 2½ times the yield of protein, with no additional nitrogen fertilizer, if planted to a compatible grass-legume association.

It should be noted, however, that the increase in protein in the combinations was not due to an increased protein yield of the Merker grass. The grass grown in combination with the nitrogen-fixing legume produced no more protein than the grass grown alone (Table II). Nearly two-thirds of the protein from the combinations came from the legumes themselves largely because of their high protein percentage. The failure of the grass to benefit from the legumes in these trials was probably due to the fact that the legumes were harvested and removed from the plots. If the legume had been incorporated in the soil, or if the plots had been pastured so that more of the nitrogen would have been returned to the soil by decaying leaves and manure, an increased protein content of the grass could have been expected.

Temperate-zone grass-legume associations have been investigated by many workers since early in the century. In general, field studies have shown grass-legume combinations to be more productive than either grass or legume grown separately. Two recent fundamental studies on the interactions of various Temperate Zone grasses and legumes in association (1, 7) have shown the response to be compensating—that is, in general, when one component of a mixture produces more dry weight or total nitrogen than in pure stand, the other component produces less. Where gains in dry weight and total nitrogen due to associations were noted (7) they have been attributed to a more effective use of the total soil area involved.

In the present study it seems clear that the increased yields of the associations were not due to individual benefit of either the grass or the legume, but rather that each component grew and produced almost as though the other were not present. This might suggest that the grass and legumes, alone, had not been sown at a sufficiently heavy rate to utilize all the available soil and light. This possibly is true for Merker grass; although planting distances were the same as those generally used for commercial plantings on the island. The kudzu, however, whether grown alone or in association with grass, made a complete ground cover in a period of some 6 to 8 months, and it is unlikely that heavier seeding would have increased its yield.

It seems more likely that the increased yields of the associations in the present tests were due to a more efficient use of available soil, sunlight, and moisture. The roots of 2-year-old tropical kudzu plants are known to penetrate to a depth of 4½ feet (9), and trailing indigo probably also is deep rooted. These legumes, therefore, are able to tap areas of the soil not accessible to the grass roots. In addition, the tall growth habit of Merker grass (usually 6 to 8 feet when harvested), which places most of its leaves well above the level of the legumes, and the high light intensity in Puerto Rico probably make it possible for both members of an association to secure adequate amounts of light.

After this work had been started, rather serious toxicity symptoms were reported from feeding trailing indigo to livestock (3, 8). As a result of these findings, the use of trailing indigo for forage cannot be recommended until the nature of the toxicity is better understood, or until methods of management or non-toxic varieties are developed.

LITERATURE CITED

1. Aberg, Ewert, Johnson, I. J., and Wilsie, C. P. 1943. Associations between species of grasses and legumes. *Jour. Amer. Soc. Agron.* 35: 357–369.
2. Loustalot, A. J. and Cernuda, C. 1949. Effect of tropical kudzu on yield and composition of forage grasses. *Trop. Agric.* (*Trin.*) 25: 41–44.
3. Nordfeldt, S., and Younge, O. R. 1949. Toxicity of creeping indigo to livestock. *Hawaii Agr. Expt. Sta. Progress Notes* No. 55.
4. Paterson, D. D. 1944. Grassland management in the West Indies. *Imp. Bur. Pastures and Forage Crops Bull.* 31.
5. Paterson, D. D. 1945. Ensilage investigations with tropical forages. *Trop. Agric.* (*Trin.*) 22: 43–48.
6. Rivera Brenes, L. 1947. The utilization of grasses, legumes, and other forage crops for cattle feeding in Puerto Rico. *Jour. of Agr. Univ. of P. R.* 31: 180–189.
7. Roberts, James L., and Olson, Frank R. 1942. Interrelationships of legumes and grasses grown in association. *Jour. Amer. Soc. Agron.* 34: 695–701.
8. Rosenberg, M. M. and Palafox, A. L. 1950. The effect of creeping indigo (*Indigofera endecaphylla*) when fed to growing chickens. *World's Poultry Science Jour.* 6: 284–291.
9. Telford, E. A., and Childers, N. F. 1947. Tropical kudzu in Puerto Rico. *Puerto Rico* (*Mayaguez*) *Fed. Expt. Sta. Cir.* 27.

(*Received for publication March*, 1952)

OBITUARIES

Sir ALGERNON ASPINALL, K.C.M.G., C.B.E., B.A.

It was with great sorrow that we received the news of the death on 6th May, 1952, of Sir Algernon Aspinall. Sir Algernon was Secretary of the West India Committee for forty years, from 1898 until 1938, and thereafter was a member of the executive committee until 1945, and was vice-president from 1939 until the time of his death. He was honorary secretary of the Tropical Agricultural College Committee appointed by Lord Milner in 1919 whose deliberations led to the foundation of the College in 1921; Secretary of the College from its inception as the West Indian Agricultural College in 1921, and as the Imperial College of Tropical Agriculture in 1924, until 1940. So valued was his advice and experience however, that when he retired from the post of Secretary to the College, the Governing Body retained his services as Consultant until he was forced to give up work in 1949.

Sir Algernon was thus intimately associated with the development of the College from its very modest beginnings to the unique and still expanding institution it is today, and no small part of the credit for this development belongs to him.

The following is an extract from a resolution which appeared in the minutes of the 256th Meeting of the Governing Body of the College : " That the Governing Body of the I.C.T.A. desire to record the sense of profound sorrow with which they have learnt of the death on 6th May of Sir Algernon Aspinall . . . . . They record at the same time their high appreciation of his great gifts of tact and initiative which he at all times devoted to the work of the College. Further, that the Governing Body desires to convey to Lady Aspinall their extension of sincere sympathy in the great loss which she has sustained ". Mr. J. M. Campbell, vice-chairman of the Governing Body, said of him at the annual general meeting of the West India Committee on 28th May, " He gave all the best years of his life to his work in the interests of the British West Indies, British Guiana and British Honduras. If of any man it was ever true to say that he was tireless in his devotion to and enthusiasm for his work, that man was Sir Algernon Aspinall ". We who knew him during his active years can well endorse these sentiments.

Among additional responsibilities he shouldered were those of honorary secretary of the West Indian Contingent Committee during the first World War; one-time chairman of the Cacao Association of London; founder member of the British Cotton Growing Association; chairman of the West Indian Produce Association ; and the first honorary secretary and later the president of the West Indian Club.

Sir Algernon was the recipient of Royal honours four times. He was made a Companion of the Most Distinguished Order of St. Michael and St. George in 1918, a Commander of the Most Excellent Order of the British Empire in 1926. He received his knighthood in 1928, and was promoted to the rank of Knight Commander of the Order of St. Michael and St. George in 1939.

His books on the West Indies are well known to traveller and scholar alike. Best known is probably his " Pocket Guide to the West Indies " ; the others are " West Indian Tales of Old " and " A Wayfarer in the West Indies ".

Sir Algernon was married in 1907. To Lady Aspinall we extend our most sincere condolences in mourning the death of a very good friend of the West Indies, and of a great man.

:: :: ::

STEPHEN A. ADEPEGBA, B.SC., A.R.C.S.

On the evening of 23rd March, 1952, Stephen Adepegba was returning to the College with some friends after spending the day in San Fernando, when the car in which he was travelling was involved in an accident and he was killed instantaneously.

The tragic news came as a great shock to all at the College for in the six months he had spent here he had proved himself keen and efficient in his studies and exceedingly popular with his fellow students. Working for the Diploma in Tropical Agriculture, he had made good progress with his research project on cherelle wilt in cocoa, but his work and studies did not preclude his regular appearance on the football field and tennis courts. His great enthusiasm in life was always accompanied by a cheerful and likeable personality.

Stephen Adepegba was born in Abeokuta, Nigeria in 1921. After taking the Diploma of Yaba Higher College he became an Assistant Agricultural Officer in the Nigerian Department of Agriculture. In 1947, he went to London to continue his studies and graduated from London University in 1951 with the degree of B.Sc. (2nd class Hons. Botany) and the Associateship of the Royal College of Science.

From the College he would have returned to his native Nigeria with a first class training and valuable experience. He should have made his mark there, for his country badly needs men of his calibre and training. His tragic death so early in his career is a great loss to Nigeria.

To his family we extend our deepest sympathy on his death made so much harder by his great distance from home.—D.B.M.